



SAFETY STANDARDS OF PKN ORLEN S.A.

***Occupational Health and Safety guidelines for designers
from the Comprehensive Prevention System of PKN
ORLEN S.A.***

Coordination:

Team
Group OHS and Prevention
Coordination Department

Acceptance:

Manager
Group OHS and Prevention
Coordination Department

Approval:

Head of the
Occupational
Health and Safety Office

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Guidelines for designers resulting from regulations of the Comprehensive Prevention System regarding:

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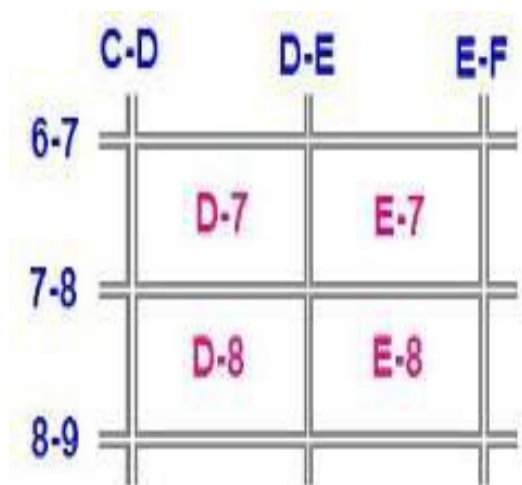


Fig. 2 Example of roads and plots marking

The land owner / tenant of the site is responsible for maintaining the health and safety at work, fire protection and environmental protection in the assigned area.

The owner of infrastructure network (structures without pipelines, sewage systems, bridges, working platforms, fittings and accessories) is the Technical Infrastructure Department.

Technological pipelines, located on piperacks and troughs, are managed by the individual managers of organizational departments (production installations).

The piperacks and main troughs are assigned in the area of supervision to individual landowners independently of the basic unit of land division, which is a technological plot.

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2. Regulation regarding the occupational health and safety requirements for employees at workplaces where explosive atmospheres may occur at the PKN ORLEN S.A.

For workplaces where the possibility of an explosive atmosphere threatening the health and life of workers is suspected, a classification of potentially explosive zones and an explosion risk assessment based on it should be performed.

The explosion risk assessment is an integral part of the Explosion Protection Document called the Ex Document.

The explosion risk assessment should include at least:

- assessment of the probability and time of occurrence of an explosive atmosphere;
- assessment of the probability of occurrence and activation of ignition sources, including electrostatic discharges;
- assessment of the interaction of the installations operated, the substances and mixtures used and the processes involved;
- assessment of the size of the anticipated (possible and undesirable) effects of the explosion.

Identification of explosive atmospheres

Characteristics of hazardous substances in terms of explosives

List and characteristics of explosive hazardous materials developed based on Ex approved and accepted classification cards for hazardous areas - Appendix No. 2.1

Classification of potentially explosive atmospheres

List and classification of potentially explosive atmospheres prepared on the basis of Ex approved and accepted classification cards for hazardous areas (Appendix No. 2.2).

Explosion risk assessment

The probability of occurrence of effective sources of ignition

It is recommended to classify effective ignition sources, taking into account the probability of their occurrence as follows:

- sources of ignition that can occur constantly/ continuously or frequently (10^0 - 10^{-2})
- sources of ignition that may rarely occur (10^{-3} - 10^{-5})
- sources of ignition that may occur exceptionally (10^{-6} - 10^{-7})

The analysis should cover all types of ignition sources given in the PN-EN 1127-1 standard, determine their effectiveness and probability of occurring in the considered space using the risk matrix.

Note: we assume higher probability values to estimate the explosion risk.

The probability of an explosive atmosphere

We estimate the likelihood of an explosive atmosphere based on the risk matrix presented in the table below:

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Type of explosion hazard area	Description of the zone	Duration	The probability of atmosphere occurring
Zone 0	A space in which an explosive atmosphere containing a mixture of combustible substances, in the form of gas, steam or mist with air, occurs continuously or in long periods	>1000 hour/year	$10^{-1} \div 1$
Zone 1	A space in which an explosive atmosphere containing a mixture of combustible substances with air may occur under normal operating conditions	$10 \div 1000$ hour/year	$10^{-3} \div 10^{-2}$
Zone 2	A space in which during the conditions of normal operation the appearance of an explosive gas atmosphere does not occur, and in the case of occurrence, it is short-lived	$1 \div 10$ hour/year	$10^{-4} \div 10^{-3}$

Note: we assume higher probability values to estimate the explosion risk.

Determination of explosion risk

To estimate the explosion risk, there is used a process risk matrix included in the ordinance on the introduction and application of the Process Safety Management System at the PKN ORLEN SA is used.

Attention:

The probability of an explosion is the presence of the product multiplied by the probability of the appearance of effective ignition sources and the occurrence of an explosive atmosphere.

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Category of effects (S)			<i>negligible</i>	<i>small</i>	<i>average</i>	<i>big</i>	<i>disaster</i>
Frequency of effects 1/year (P)		<i>numeric designation</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
<i>very often</i>	$<10^0 - 10^{-1}$	<i>1</i>	TA	TNA	NA	NA	NA
<i>often</i>	$<10^{-1} - 10^{-2}$	<i>2</i>	TA	TNA	TNA	NA	NA
<i>possible</i>	$<10^{-2} - 10^{-3}$	<i>3</i>	TA	TA	TNA	TNA	NA
<i>sporadic</i>	$<10^{-3} - 10^{-4}$	<i>4</i>	A	TA	TA	TNA	TNA
<i>rare</i>	$<10^{-4} - 10^{-5}$	<i>5</i>	A	A	TA	TA	TNA
<i>very rare</i>	$<10^{-5} - 10^{-6}$	<i>6</i>	A	A	A	TA	TA
<i>nearly impossible</i>	$<10^{-6} - 10^{-7}>$	<i>7</i>	A	A	A	A	A

Where the resulting risk level (R) is determined by:

- A** Risk accepted (in theory no additional security measures are required, however, they may be indicated for implementation),
- TA** Risk tolerated - accepted (ALARP principle, review the alternatives)
- TNA** Accepted unacceptable risk (introduce additional safety measures on a separate date)
- NA** Unacceptable risk (stop the process immediately)

Categories of effects:

effects	Employees	Population	Environment	Wealth	Reputation
negligible	No injuries	No injuries	No influence	To 10 000 €	No influence
small	Single minor injuries. (Not affecting the performance of work or	Odor, noise (No evacuation required or first medical aid required)	Small recorded in reports. (Light environmental destruction within the installation)	To 100 000 €	A slight impact (Missed trustees - possible to recover quickly at low cost.

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effects	Employees	Population	Environment	Wealth	Reputation
	causing inability to work)				Public awareness may exist)
average	Average injuries, single severe injuries <i>(Limiting performance of duties or a few days absence for full recovery, small, reversible health effects, eg skin irritation, food poisoning)</i>	Small injuries <i>(No evacuation required, first pre-medical help required)</i>	Average damage <i>(Clearly destruction or emission to the environment, but no lasting effect, single case of violation of a statutory restriction or a single complaint)</i>	To 1.000 000 €	Limited impact <i>(Conflicted trust - possible to regain in the long term with PR support. Unpleasant attention of local media / political groups)</i>
big	Numerous heavy injuries <i>(Irreversible health effects with serious inability to work, for example: caustic burns, loss of hearing due to detonation noise, heat stroke)</i>	Average injuries <i>(Limited health effects for people not required evacuation, medical assistance required for individual cases)</i>	Serious destruction <i>(The company must undertake comprehensive measures to rebuild environmental damage, the extent of damage violates statutory restrictions)</i>	To 10 000 000 €	National influence <i>(Significant drop in confidence - trust that can be recovered in the long term, but at a high cost. Extensive, unfavorable national media attention)</i>
catastrophic	Fatalities <i>(Single or collective fatal accident)</i>	Serious injuries <i>(Irreversible health effects, required evacuation and medical help for a large number of people)</i>	Ecological disaster <i>(Permanent and serious damage to the environment resulting in large financial consequences for the Company, ongoing effects seriously violate statutory restrictions)</i>	Above 10 000 000 €	International influence <i>(Seriously tarnished confidence - impossible to recover fully. International public attention, extensive, unfavorable international media attention)</i>

The result of the explosion risk assessment should be presented in the table. Appendix **No.2.3**

List of potentially explosive workplaces

The list of potentially explosive workplaces should be presented in the table. Appendix **No. 2.4**

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Measures to prevent the occurrence of explosive hazards and to reduce the effects of an explosion

The following is a sample of an example table:

Item	Workplace	Explosion prevention agent used	The date of the review	Responsible person
1				
2				

Specification of explosion-proof devices

Define the specification of explosion-proof devices installed on the site - mechanical, electrical, automatic, teleinformatic. It is necessary to apply to all industries for providing specimens of device specification tables - Appendix **No. 2.5**

List of certificates for explosion-proof devices

The list of certificates for explosion-proof devices should be prepared with the division into individual industries - mechanical, electrical, automatic, teleinformatic as per Appendix **No. 2.6**

3. Regulations regarding the classification of potentially explosive atmospheres in PKN ORLEN S.A. and in companies of the ORLEN Capital Group.

The scope regarding the classification of potentially explosive atmospheres is included in the Technical Requirements of the Electric Industry (issue 2.7 or later), item 2. transferred or provided to the Contractor.

4. Operational regulation regarding recording, setting up and removal of plugs on the premises of PKN ORLEN S.A.

The most effective way to cut off the medium is to install a suitable blind on the flange connection. Apparatus, devices and pipelines containing the following media: flammable and explosive, corrosive and stinging, toxic, technical gases, hot water, steam and other hot media should be absolutely blinded for technological, renovation, investment purposes, etc. In the case of a plug protecting the workplace against the appearance of hazardous energy, it is covered by the LOTO system. The LOTO lock is placed on the end cap in accordance with the detailed LOTO instruction for a given Department / Installation. The plugs must be of appropriate diameter, thickness and made of a material capable of withstanding pressure, temperature and corrosive effects of media on the active side, and should have a "eyepiece" or "eye" - a round end protruding above the joint.

5. Regulation on the application of the Process Safety Management System at the PKN ORLEN S.A.

The Process Safety Management System is part of the overall management system at PKN ORLEN SA.

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The Production Facility in Płock, the PTA Facility in Włocławek and the Company's fuel terminals have been classified as an increased or high hazard worksites (upper-tier establishments).

All classified facilities have documentation adequate to the classification of:

- registration of the Facility
- Prevention Program

And for high-risk worksites also:

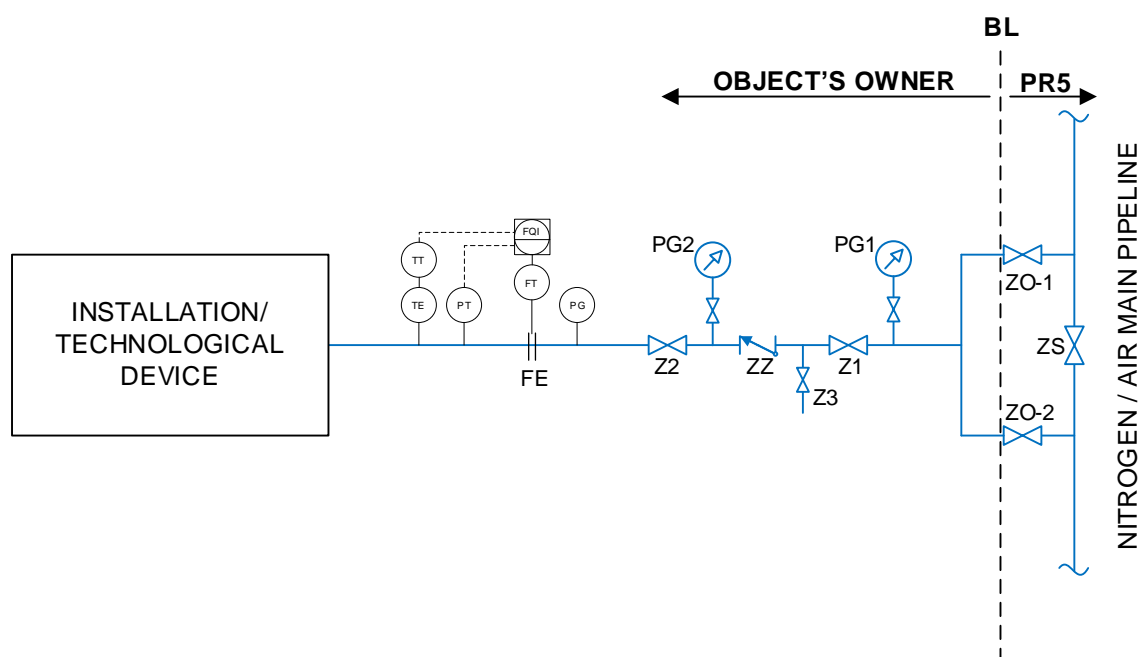
- Safety Report
- Internal Operation and Rescue Plan,
- Quantitative list of hazardous substances as of December 31 of each year.

Hazard analyzes are carried out at every stage of the installation's life. PHA and HAZOP methods are most commonly used. The results of analyzes should be documented. Review of the analyzes should be carried out at least every 5 years.

Process Analyzes are assessed by the Analytical Team and process safety assessments are made by the Process Safety Committee.

Conducting hazard analyzes and assessing the physical effects of emergency events – Appendix **No. 2.7**

6. Operational regulation regarding securing nitrogen and air pipelines against their contamination with dangerous media at the Production Facility in Płock.



Marking:

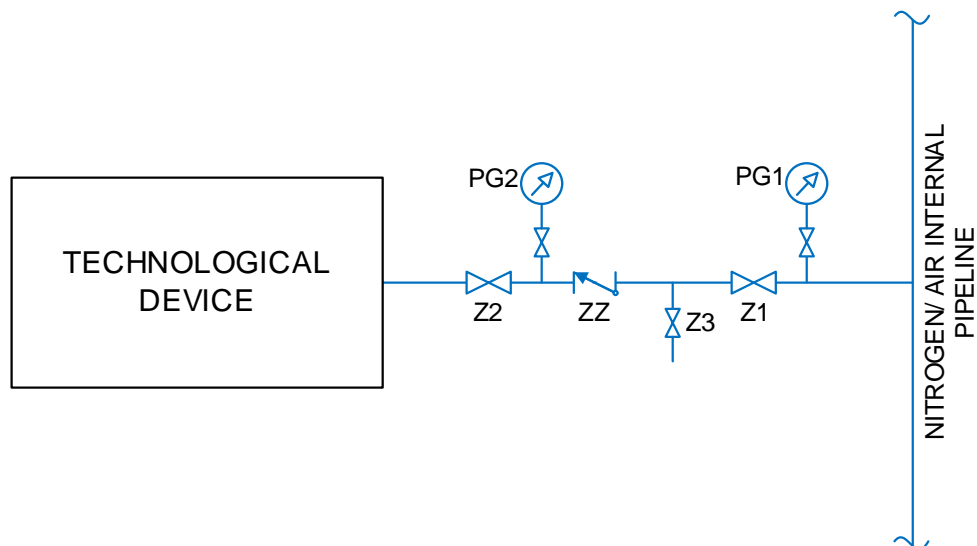
- Z** – shut-off fittings
- ZZ** – check valve
- ZS** – section shut-off fittings
- ZO** – main shut-off fittings
- PG** – manometer
- FE** – flange (example of the measuring system based on the pressure difference)
- BL** – Battery Limit

Fig. 1

The above diagram does not take into account the place of installation of the eyepiece plug, the location of which is within the control of the owner of the installation / technological device

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Installations and technical equipment supplied with nitrogen or air should be connected to the main pipelines in a way that will prevent contamination of main pipelines with hazardous media, and their connection with main pipelines must be made in accordance with Figure 1.



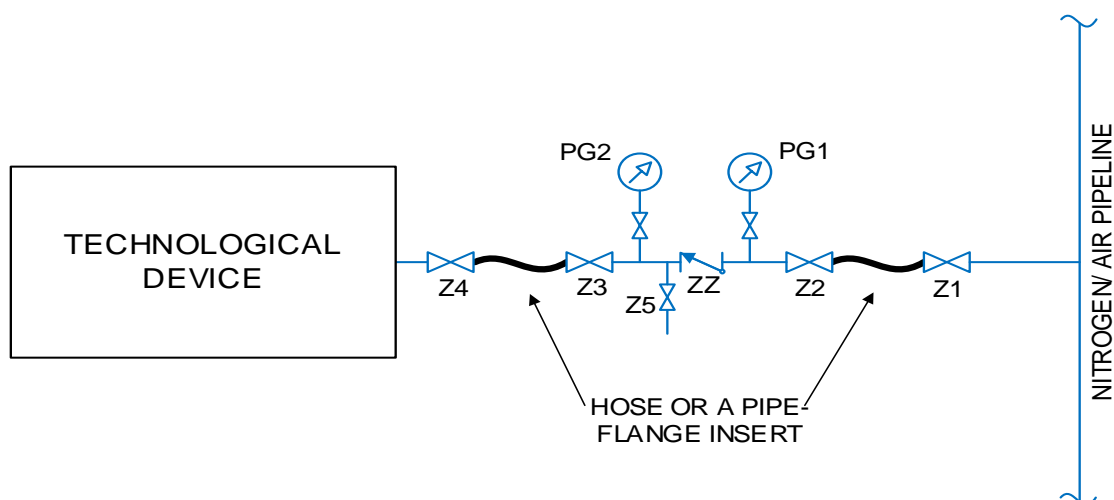
Marking:

- Z** – shut-off fittings
- ZZ** – check valve
- PG** – manometer

Fig. 2

The above diagram does not take into account the place for installation of the eyepiece plug, the location of which should be taken into account by the owner of the technological device.

For continuous supply of technological devices with nitrogen or air, their connection to internal nitrogen or air pipelines must be made in accordance with Figure 2.



Marking:

- Z** – shut-off fittings
- ZZ** – check valve

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PG – manometer

Fig. 3

When supplying process equipment with nitrogen or air, connection with nitrogen or air piping must be carried out in accordance with Figure 3.

Colors of hoses used to connect energy media on the premises of PKN ORLEN:.

- white or black with white elements, e.g. stripes for nitrogen;
- blue or black with blue elements, e.g. stripes for air or water;
- red or black with red elements, e.g. stripes for steam;
- colors other than the above-mentioned for media not included in this ordinance i.e. acid, lye, etc.

All new connections to the main nitrogen/air pipelines should be previously agreed and approved by representatives of PKN ORLEN and equipped with appropriate fittings:

- Gate valves
- Check valves
- Manometers
- Drains
- Measuring systems with flow and pressure visualization in the system of the currently functioning real-time database of PKN ORLEN S.A., e.g. PI ProcessBook,



Fig. 4

Fittings and pipelines supplying nitrogen and air to technological equipment should be described and marked in accordance with the rules in force at the Production Facility in Płock.

Nitrogen ignition switch should be equipped with technical solutions that make it impossible to connect a flexible hose to a medium other than nitrogen to the ignition switch.

During the investment stage, it is allowed to temporarily connect nitrogen and air from the main pipeline to the building under construction using the existing connectors.

7. Regulation regarding the implementation of "Instructions for the control and operation of PiA interlock systems in the Production Facility of PKN ORLEN SA in Płock and the PTA Facility in Włocławek".

The PiA locking system is a significant safety layer independent of the basic control system. The purpose of the locking system is to reduce the risk of consequences of the threat for which it has been designed. In case of exceeding the limit values of the process parameters, the locking system executes automatically, without intervention of the operator, the activities that ensure

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the shut down of the technological object in a safe manner. Service schedules for blocking systems are created based on the results of SIL (safety integrity analysis). The SIL analysis relies on a qualitative and quantitative risk assessment of the operation of technological installations and takes into account the probability of occurrence of events and their consequences. Changes in technological blocking systems, in particular regarding the implementation of blocking functions, set initiators and test intervals, may be made at the request of the person managing the Department / Block / Division, after approval by appropriate Fire and Technical Committees. Activating the MOS switch (Maintenance Override Switch) disables the control of a given locking parameter, therefore it should be used only in particularly justified cases limited to the necessary service needs. The duration of MOS in the active state should be as short as possible. Deactivation of the possible activation of the interlock circuit as a result of the predicted actual exceeding of the parameter controlled by the initiator is not covered by the design purpose of the MOS switch.

8. Regulations regarding the implementation of a fire protection standard for production installations for use in investment and modernization processes at PKN ORLEN S.A.

In order to ensure the same technical requirements for the Production Facility in Płock (excluding the Fuel Terminal in Płock and the Railway Terminal in Płock), the PTA Facility in Włocławek and CCGT Facility in Włocławek for investment projects and tasks, there are introduced "The guidelines for the design of fire protection for new and modernized production installations of PKN ORLEN S.A.

Business Owners are responsible for establishing the Team to evaluate the proposed solutions for fire protection.

The team, etc., for fire protection assessment, evaluates:

- fire risk analysis,
- project for the selection of passive fire protection measures,

after which he draws up a report from the work.

The potential for fire is considered to be devices, apparatus containing flammable substances of class I, II, and III with a flash point up to 100 ° C or operating at a temperature above the self-ignition temperature.

The main elements subject to passive fire protection:

- elements of shelves constituting the main supporting structure,
- elements of piperacks constituting the main supporting structure,
- supports for tanks, reactors and other vertical devices,
- air cooler supports,
- tank beds and horizontal braces,
- power installations and energy,
- technological protection systems.

Fireproof materials selection and execution

Required safety properties of fire protection:

- suitability and effectiveness in hydrocarbon fires,
- asbestos content is excluded,
- durability of at least 15 years,

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- resistance to rapid changes in temperature caused by a stream of water when extinguishing a possible fire,
- the initiation and maintenance of processes detrimental to the durability of the structure (etc., processoric) is excluded,
- resistance to external weather conditions.

Construction products intended for use must have the necessary approvals in accordance with the Construction Products Act of 16 April 2004 (JoL.2004, no.92 pos. 881, as amended)

The technical specification may only be:

- according to the European system, in the case of CE marking - a harmonized standard, a European technical approval or a national technical specification of a product of a Member State of the European Union or the European Economic Area, recognized by the European Commission as compliant with the basic requirements.

9. Regulation on the implementation for business use of the "Fire and Chemical Safety Regulations of PKN ORLEN S.A."

General organizational and ordering rules related to fire and chemical safety of PKN ORLEN S.A. facilities.

- Fire Safety Instructions should always be available to employees (in paper or electronic form) and to the emergency services (in paper form).
- All PKN ORLEN S.A. facilities must be provided with instructions on proceeding in the event of fire, chemical accident or other local emergency, including a list of emergency numbers, in a public place.
- All production and storage facilities, buildings and back-up facilities should be marked with a plate indicating the name of the facility / company and the person responsible for fire and chemical safety of the given facility, with a 24-hour/day contact telephone number. In fuel terminals outside Płock, such information should be placed in the porter's lodge, which is supervised 24/7 by the prevention.
- As a rule, the location of the assembly point for evacuation is the northeast corner of each plot.



- On the premises of PKN ORLEN S.A. smoking cigarettes and alternative products are forbidden, except for properly arranged smoking rooms marked with the information "TU WOLNO PALIĆ" or "PALARNIA". In buildings where there is no technical possibility to create a smoking room, smoking cigarettes and alternative products are strictly forbidden. The smoking room should be equipped with mechanical exhaust ventilation or a filtration system preventing the penetration of tobacco smoke to other rooms, handheld fire-fighting equipment and ashtray for extinguishing cigarette butts. If the smoking room is located in production, workshop or back-up facilities, it must be additionally equipped with a water container to extinguish cigarette butts.
- It is allowed to:

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- organize permanent outdoor smoking rooms in the form of temporary construction facilities. Permanent outdoor smoking rooms must be made of non-flammable and non-fire spreading elements.
- organize temporary outdoor smoking rooms for employees of external companies for the duration of renovation/investment works on installations emptied of utilities, enclosed to a height of at least 0.5 m with a housing made of non-flammable material. It must be equipped with a water container to extinguish cigarette butts,
- organizing temporary outdoor smoking rooms for employees of external companies for the duration of renovation/investment works on installations in the form of a closed temporary cubature facility made of non-combustible materials. It must be equipped with a water container to extinguish cigarette butts,

Outdoor smoking rooms must be located at least 30 m from the designated explosion hazard zones and at least 10 m from cubature facilities. Sewerage chambers must be secured within a 20 m radius from the outdoor smoking room. Outdoor smoking rooms must be equipped with handheld firefighting equipment and ashtray to extinguish cigarette butts. It is recommended to create 1 temporary smoking room per 200 Contractor's employees. The smoking room should have an area of at least 10 m². The location of the smoking room should be indicated by the manager of the organizational unit and the Head of the Company Fire Brigade (for facilities located in Płock and Włocławek), and for facilities located outside Płock and Włocławek with an authorized employee of the ORLEN Eko Sp. z o.o.

- Social and assembly facilities of external enterprises located on the premises of production facilities should be organized in such a way as not to impede communication on internal roads and to prevent access to fire-fighting devices. Each facility and each temporary facility must be marked in such a way that the owner can be identified, and also with the person to contact (including the contact telephone number). The location of the facilities at the Production Plant in Płock must be agreed with the Commander of the Company Fire Brigade, and for the PTA and CCGT Plants in Włocławek, fuel terminals and other facilities located outside Płock and Włocławek – with an authorized employee of ORLEN Eko Sp. z o.o.
- It is forbidden to block entries to the installation area in a way preventing entry of rescue vehicles.
- Storage of technical gases at the Company's premises should be carried out in accordance with state regulations.
- Fire and chemical safety inspections at the Company's premises may be conducted by:
 - Employees of the Company Fire Brigade,
 - Employees of the Group OHS and Prevention Coordination Department,
 - Employees of ORLEN Eko Sp. z o.o. in accordance with the scope of contracts.
- Ad hoc inspections of the state of fire and chemical safety can be carried out by Managers of facilities in their area. As part of patrol activities, security service employees have the right to check whether the fire and chemical safety rules are enforced in the Company's facilities and companies conducting work at PKN ORLEN S.A. Security officers immediately inform the Commander of the Company Fire Brigade about all irregularities found in the field of fire and chemical safety. In disputes regarding the controls of fire and chemical safety, you can appeal to the Head of the Occupational Health and Safety.

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When performing fire hazardous works, you need to:

- protect combustible materials against fire, occurring in the place of work and in adjacent areas, including elements of the structure of the object, and related technical installations;
- secure drains within a minimum radius of 20 m;
- carry out fire-hazardous works in potentially explosive atmospheres or in spaces where other work has previously been carried out related to the use of flammable liquids or flammable gases, only if the concentration of the vapors of liquids or gases in the mixture with air at the place of work does not exceed 10% of their lower explosion limit;
- have at the place of work equipment enabling the elimination of all sources of fire;
- organize and control the place where the works were carried out and in the adjacent areas;
- provide technically efficient equipment designed to carry out work in accordance with the principles of health and safety and fire safety.
- during work, use extreme caution, eliminate the potential of the source of fire and the observed sources of fire, and in the event of a situation threatening with fire, chemical failure or other local threat stop working.
- It is the duty of the person carrying out fire-hazardous works to comply strictly with the conditions set out in the written permit.
- All employees of external entities conducting work at PKN ORLEN S.A. are required to acknowledge and comply with the provisions on fire and chemical safety in force at the Company's premises.

Procedures and rules on acceptance of fire protection documentation:

- The Company Fire Brigade gives opinion on documentation only and exclusively in the field of fire protection.
- In order to issue an opinion on documentation in the field of fire protection, projects should be submitted to the Company Fire Brigade in a paper version in Polish, and prepared in accordance with applicable regulations agreed (without comments) with an appraiser in field of fire protection.
- Projects should provide feedback before submitting them to the appropriate office (construction projects) or for implementation (technical and executive designs).
- The Company Fire Brigade gives opinion on fire safety documentation within 14 days since the date of delivery.
- In specific situations, the period of giving the opinion may be extended.
- The fire protection conditions in construction projects must be a separate chapter.
- Scopes for fire-fighting equipment in industry projects must be separate chapters.
- The Company Fire Brigade issues an opinion on the construction project based on the following data included in the project documentation:
 - information on the area, height and number of stories;
 - fire and chemical hazard characteristics, including the parameters of fire hazardous materials, risks of technological processes and depending on the needs – fire characteristics adopted for design purposes;
 - information on the hazard category for people and the expected number of persons on the site and on each floor;
 - information on the expected fire load density;
 - assessment of the explosion hazard in rooms and external spaces;
 - information on fire resistance class, fire integrity class and fire spreading degree of construction elements;
 - information about the building division into fire zones and smoke zones;

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- location information regarding fire and chemical safety, including distances from neighboring facilities;
- information about the conditions and strategies for evacuating people or saving them in a different way;
- information on the method of fire protection of utility installations, in particular ventilation/ air conditioning, heating, gas, electricity, teletechnical and lightning protection installations;
- information about the selection of fire-fighting equipment and other fire and chemical safety devices, adapted to the requirements under the regulations concerning fire protection and fire scenarios adopted, with the basic characteristics of these devices;
- information on equipping the facility with fire extinguishers;
- information about the fire water supply for external fire fighting;
- information on the preparation of the construction object and the area for carrying out rescue and firefighting operations, in particular information on the fire road;
- the need for additional equipment necessary for the Company Fire Brigade.

Rules for alerting and informing people and emergency services

Every employee who has noticed a fire, chemical accident or other local threat is absolutely obliged to warn people nearby as well as notify their superiors and alert:

- Company Fire Brigade - in the case of facilities at the Production Plant in Płock or other appropriate fire protection unit,
- Company Fire Brigade of ANWIL S.A. – at the PTA and CCGT Facilities in Włocławek,
- the nearest local unit of the State Fire Service (for other facilities outside Płock and Włocławek) by calling the telephone numbers:

19 998 – Company Emergency Number in Płock

19 998 – PTA and CCGT Facilities in Włocławek

998 or 112 – The State Fire Service throughout the country.



The emergency report should be short, concise and clearly define:

- place of fire, chemical failure or other thread,
- existence of danger to people,
- type of released substance,
- name and phone number from which you are calling;
- other data allowing a proper decision on the disposition of forces and resources by the person receiving the notification.

Announcement of chemical alarms

Production Facility in Płock

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In the event of a chemical accident hazard, a chemical alarm in one of three phases is announced:

Phase "I" alarm - it is announced when the hazard range covers the installation node or installations, not exceeding the boundary plot - main roads. The alarm is announced by an alarm siren or buzzer, with **modulated sound signals lasting 3 minutes**.

Phase „I” alarm is announced by the facility manager or a person authorized by him (e.g. Shift Supervisor). If a large amount of hazardous substances suddenly escapes (e.g. hydrogen sulfide, liquefied gas), any employee who notices this occurrence may issue an alarm.

Phase "II" alarm – it is announced when the threat exceeds the area of one plot or one installation. The **phase "II" alarm** is announced by repeating the **phase "I" alarm** sound signals by alarm sirens from several or all facilities at the Production Plant in Płock. The decision to announce the phase "II" alarm is made by the Head of the Rescue Operation (KAR) or the Head of Rescue Activities (KDR) in consultation with the Central Production Scheduling and Coordination Department.

At the same time, information about the announcement of the **phase "II" alarm** is transmitted via the Warning and Alarm System messages.

Phase "III" alarm – the phase „III” chemical alarm is a continuation of the **phase "II" alarm** and it is a consequence of the development of the action outside the fencing area of the Production Plant in Płock. The activities are carried out on the basis of the External Emergency Plan. The decision to announce the phase "II" alarm is made by the Head of Rescue Activities (KDR) in consultation with the Central Production Scheduling and Coordination Department.

PTA and CCGT Facilities in Włocławek

In the event of a chemical accident at the premises of PTA and CCGT Facilities in Włocławek, the following chemical alarms are issued depending on the scope and direction of the threat.:

- 1st degree chemical alarm
- chemical alarm - warning
- 2nd degree chemical alarm
- 3rd degree chemical alarm

1st degree chemical alarm

The 1st degree chemical alarm is announced in the event of a local chemical threat on the premises of the PTA or CCGT Facilities in Włocławek, which does not threaten the areas adjacent to the plant. The alarm is announced by means of a horn with intermittent sound signals lasting 2 sec. with breaks of 1 sec. Total signal transmission time is 3 minutes. The 1st degree chemical alarm is announced by the head of the PTA Plant or the CCGT Włocławek Plant or a person authorized by him (e.g. Shift Supervisor). In addition, a light signal is generated.

Cancellation of the 1st degree chemical alarm is done by a verbal signal (voice announcement). The 1st degree chemical alarm is canceled by the head of the PTA Plant or the CCGT Włocławek Plant or a person authorized by him (e.g. Shift Supervisor).

Chemical alarm - warning

Chemical alarm - warning is used to alert employees about occurrences on the premises of the PTA Plant, CCGT Włocławek Plant or ANWIL S.A. of a threat not threatening the areas adjacent to the plant. Chemical alarm - warning is announced by the Company Dispatcher at

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ANWIL S.A. The verbal signal is accompanied by a continuous acoustic signal lasting 1 minute.

Chemical alarm - warning is dismissed by the Company Dispatcher at ANWIL S.A. through an appropriate message.

2nd degree chemical alarm

The 2nd degree chemical alarm is announced in the event of a local chemical threat at the premises of PTA or CCGT Włocławek with the possibility of extension to ANWIL S.A. production installations or Indorama Ventures Poland Sp. z o.o. The alarm is announced by means of an intermittent acoustic signal (modulated) of sirens lasting 3 minutes and the transmission of an appropriate message by the Company Dispatcher at ANWIL S.A.

3rd degree chemical alarm

The 3rd degree chemical alarm is a continuation of the 2nd degree alarm and is a consequence of the development of the action outside the fence of the PTA Plant. The 3rd degree chemical alarm is announced by the Company Dispatcher at ANWIL S.A. The light signal is accompanied by an intermittent acoustic signal (modulated) of sirens lasting 3 minutes. Additionally (depending on the wind direction) the "stop" traffic lights can be turned on on the roads:

- national no 1,
- local Krzywa Góra-Gąbinek,
- local Włocławek – Brzezcie.

Cancellation of the 2nd and 3rd degree chemical alarm is done by a continuous acoustic signal of sirens lasting 3 minutes and an appropriate message issued by the Company Dispatcher at ANWIL S.A.

Handheld fire-fighting equipment:

All facilities should be equipped with handheld fire-fighting equipment adapted to extinguishing these groups of fires that may occur in the facility. At the PKN ORLEN S.A. the basic unit of mass of extinguishing agent is 6 kg (in the case of powder extinguishers) or 5 kg (for snow extinguishers).

10. Regulation on the implementation of the "Instruction on the location of temporary facilities and organization of construction sites for Contractors on the premises of the Production Facility in Płock, the PTA Facility in Włocławek, CCGT Włocławek or adjacent areas".

1. Temporary back-up facility located on the premises of the production plant in Płock, PTA Plant in Włocławek, CCGT Włocławek Plant or adjacent areas for Contractors with contracts for the implementation of repair services or contracts for the implementation of works under investment projects.
2. Temporary facilities may be located within the Production Facility in Płock, PTA Facility in Włocławek, CCGT Włocławek Facility or adjacent areas only on the basis of a contract for repair, periodic, planned, current, framework, technological services or for investment projects concluded between PKN ORLEN ARE a Contractors or tenancy / lease / access agreements.
3. The Contractor who meets the provisions in point 1 - 3 applying for temporary location of facilities in the area and within the Production Facility in Płock, PTA Facility in Włocławek, CCGT Włocławek Facility or adjacent areas obtains the required approvals from the Principal

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and the Designer's Main Department, requested by the completed form "Permission for temporary Contractor's location location "

4. The Contractor shall be required to obtain the approval of the back office location by the Site Owner or the area designated by the Owner.
5. The time / period of the back office operation is valid with the deadlines specified in the contract for the performance of renovation or investment works, including the time provided for mobilization and demobilization.
6. All permits for the temporary location of the Contractor's back-up facilities are recorded by the Technical Infrastructure Department.
7. The transfer of the land for the back-up facility is carried out by protocol.
8. The contractor is responsible for the area taken over along with the facilities, until the completion of works and a formal return of the area with the surrounding surroundings.
9. 8. It is strictly forbidden to create permanent dumps and storage places for any waste in the back office and its surroundings.
10. Waste generated in the construction/ renovation process should be selectively stored, removed from the construction site and managed in accordance with applicable regulations and arrangements contained in the contract. Recommended removal cycle from the construction site is 7 calendar days.
11. The Contractor's duties include equipping the back-end with a container or container for municipal waste as well as designating and marking a place for temporary storage of waste.
12. To use the media in the back office, it is required to conclude agreements with service providers and to cover their costs by the Contractor.
13. The Contractor shall be liable under general rules provided for by civil law for damages resulting from acts or omissions in relation to equipment and installations of PKN ORLEN SA located on the given square or area - from the moment of its adoption until the moment of formal return.

Conditions for temporary back-up facilities

1. The facilities located on the premises of the Production Facility in Płock, PTA Facility in Włocławek, CCGT Włocławek Facility or on adjacent areas should be fenced in such a way as to prevent outsiders access to the back office.
2. It is allowed not to fence the facilities for carrying out renovation works, as agreed with the landowners/ users or for investment works in accordance with arrangements with appropriate Implementers or Project Implementation Managers in consultation with landowners, which does not absolve the Contractor from responsibility for the facilities and the area taken over.
3. After taking over the land (plot), the Contractor is responsible for organizing the facilities and utilities necessary for the functioning of the temporary back office facilities.
4. Each object, temporary facilities should have a visible yellow information board giving:
 - name of the Contractor,
 - name and surname of the person responsible for the object,
 - 24-hour telephone to the person responsible for the back office.
5. Fenced or back-up areas that will not have an information board will be considered as abandoned property.
6. The facilities should be located in the following distances from:
 - a) designated Ex-zones,
 - b) main lanes, networks and utilities, to ensure maximum safety of employees
7. The facilities referred to shall meet the following conditions:
 - a) the location of the min. 2 m. outside the designated danger zone specified in the classification documentation for potentially explosive atmospheres;

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- b) it is possible to locate a plug in a potentially explosive atmosphere during a shutdown or overhaul, provided that the hydrocarbon installation is empty inside a designated explosion hazard zone;
 - c) distance from other objects including railway tracks - min. 8 m,
 - d) as a rule, it is assumed that the back-up facilities will consist total of three barracks or other rooms marked with the company's name, with a total area of up to 50 m², for one Contractor;
 - e) in the case of the need to increase the number of facilities, it requires justification, confirmed by the ordering party;
 - f) outside the facilities mentioned in point 7d. a distance of at least 4 m must be kept;
 - g) distance from the main road - at least 5 meters from the road strip limit, and the facilities can not limit the visibility of the drivers moving on the road.
8. In order to ensure sufficient visibility at intersections of main roads, it is forbidden to set containers and crew wagons at a distance of less than 15 m from the road gauge.
 9. It is forbidden to set containers and crew wagons acting as social facilities under main flyovers and flares.
 10. Facilities must be equipped with hand-held fire-fighting equipment in accordance with regulations defined in Comprehensive Prevention System (further referred to as KSP), but not less than 1 unit of fire-fighting equipment for each truck or other compartment. The free access to fire-extinguishing equipment should be provided - leaving free space no less than 2 m in each direction from the device.
 11. Back - up facilities should be located in such a way as to maintain access to the installation's security devices - leaving a space of not less than 2m.
 12. The Contractor's duties include:
 - a) exercising general supervision over the behavior and compliance with the regulations as well as OSH and fire protection rules,
 - b) providing in containers or other rooms instructions in the event of fire,
 - c) maintaining cleanliness and order in the subordinate area,
 - d) compliance with the conditions that should be met by the area (yard) or facilities,
 - e) protection of the area located in (site), back-up facilities - trees, technical infrastructure and other elements of development,
 - f) safe storage of technical gases in accordance with the principles of PKN ORLEN SA.

Liquidation of the back-up facilities, transfer of premises or building sites

1. The contractor is obliged to remove their back - up facilities and transfer the area (plot) in the state defined by the contract or in the permit, after completion of the work and formal acceptance by the ordering party, unless the deadline is specified in the contract should be given in the acceptance report.
2. The Contractor shall, in the agreed scope, dismantle and liquidate the connections made for the site and submit them in the General Plan Workshop.
3. The Contractor transfers the structured area on the basis of the acceptance protocol, signed by both parties.

Social and living facilities

Social and living facilities located on the premises of a Production Facility in Płock, PTA Facility in Włocławek, CCGT Włocławek Facility or on areas adjacent to Contractors with contracts for the implementation of planned and technological repairs.

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1. For the Contractor performing works under scheduled and technological repairs, the location of the social and welfare facilities is determined by the Technical Infrastructure Department.
2. It is required to conclude contracts with service providers and to cover their costs themselves, to use the media in the social and living facilities, i.e.:
 - a) electricity and other energy media,
 - b) potable water, as indicated by meters installed at outflows or power supply,
 - c) export of solid and liquid waste,
 - d) sewage disposal.
3. The Contractor is obliged to notify 1 month before the renovation or within the time limit set by the Supervisor of the Ordering Party about the planned amount of setting his own containers:
 - office,
 - social,
 - warehouse,
 - sanitation.
4. Containers must be technically functional, aesthetic and meet all social conditions - health and safety and fire protection.
5. In order to ensure the order and aesthetics of the area of the production facility in Płock and areas adjacent to it, Contractor is obliged to independently maintain the cleanliness of the area.
6. Contractor's social and living facilities must be equipped with hand-held firefighting equipment in accordance with KSP, but not less than 1 unit of fire-fighting equipment for each barracks. Externally accessible fire-extinguishing devices must be provided - leaving adequate free space.
7. Municipal waste generated in connection with the stay of the Contractor's employees on the premises of PKN ORLEN S.A. should be placed in dedicated containers intended for selective municipal waste collection. Containers other than municipal waste, in particular hazardous waste, may not be put into containers.

Transmission of the land for construction use

Transfer of sites for construction at the Production Facility in Płock, PTA Facility in Włocławek, CCGT Włocławek Facility or areas adjacent to the Users or Land Owners for the implementation of renovation works and investment tasks from the 30000/40000 group

1. The site (plot) of construction should be transferred by protocol.
2. When transferring the construction site, PKN ORLEN S.A. represents the orderer of work, in cooperation with the supervision inspector. In the case of the construction industry - the construction supervision inspector.
3. The contractor is responsible for the acquired site, including the facilities, until the completion of works and a formal return of the area.
4. The given area (plot) of construction should be fenced and have a yellow information board, on which all information about the investment, investor, emergency numbers of telephones and telephone of the manager of a given construction must be posted.
5. Waste generated in the construction process should be selectively stored, removed from the construction site and managed in accordance with the applicable regulations and provisions of the contract. Recommended removal cycle from the construction site is up to 7 calendar days.
6. The Contractor's duties include equipping the facility plot in a container for municipal waste, and on the site of construction, designation and marking of a place for temporary storage of waste.
7. The Contractor's duties include, above all:

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- a) exercising general supervision over their conduct and observance of regulations as well as OSH and fire protection rules;
 - b) maintaining cleanliness and order in the subordinate area;
 - c) compliance with the conditions to be met by the construction site and facilities;
 - d) Organization and coordination of services;
 - e) Protection of the construction site, back-up facilities and other elements of development located in the area, unless they are foreseen for liquidation.
8. The Contractor shall be liable under general rules provided for by civil law for damages resulting from acts or omissions in relation to the equipment and installations of PKN ORLEN S.A. located on the given territory - from the moment of its acceptance, until the moment of formal return and resulting from agreements concluded between the parties.
 9. Development of the site should be made in accordance with the documentation and detailed arrangements, which should include:
 - a) land development plan / square / construction and social and assembly facilities;
 - b) arrangements with the relevant services of PKN ORLEN S.A. in the field of energy media consumption, electric power supply, etc. ;
 - c) arrangements made with the ordering parties regarding the organization and conditions of carrying out works and the validity date of the back office location;
 - d) agreeing on the scope of disassembly works after completion of works on the site;
 - e) arrangements regarding the arrangement of the area after the liquidated back office.
 10. Depending on the situation and for the needs of a given site (plot), the Contractor develops documentation containing etc. place and methods of connection to the electricity grid, teletechnical and other networks located on the site (plot) - to the analogous PKN ORLEN SA networks, as well as the identification of collection points.
 11. Handover of the Contractor's construction site for ongoing investment projects
 12. Implemented by the Property Investment Implementation Office should take into account the requirements contained in the "Instruction for the preparation and implementation of property investments in PKN ORLEN S.A.".

Permanent back-up facilities

Conditions to be met by permanent facilities located on the premises of the Production Facility in Płock, PTA Facility in Włocławek, CCGT Facility for Contractors with periodic, servicing and ongoing repairs.

1. Permanent facilities may be located on the premises of the Production Facility in Płock, PTA Facility in Włocławek, CCGT Włocławek Facility or within them only and exclusively on the basis of a contract (lease, access) concluded between interested parties in accordance with the rules of disposal in force at the Company real estate established in relevant internal acts.
2. The application for leasing / renting / providing facilities is made by the landowner supervising the property on which the facilities are to be located, to the Property Disposal Department, indicating its location and special conditions of use and special obligations of the lessee / tenant to be included in the contract in relation with the characteristics of his business or real estate status (on which the back-up facilities are to be located). The application should be accompanied by:
 - a) consent of the Security Office (for the establishment of facilities at the plant for a given contractor),
 - b) recommendation of the Occupational Health and Safety Office (in the scope of occupational safety and health, fire protection and process safety),

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- c) recommendation of organizational units responsible for the implementation of contracts with Contractors and for the settlement of these contracts, confirming that the contractor applying for the lease performs the service / for the Company, indicating the time of implementation and no objections to the cooperation with it so far),
 - d) a map with the boundaries of the leased / rented item / access agreed with the General Plan Workshop.
3. Agreements referred to in point 1 of this Chapter are prepared by the Department of Real Estate Disposal and are subject to acceptance by the Owners of leased / rented / shared areas in terms of safeguarding the legitimate interests of the Company, including the requirements for location and use of fixed facilities on terms analogous to temporary and social welfare provided for this Instruction.
4. Agreements referred to in point 1 of this Chapter should contain a provision concerning the Contractor's liability for municipal waste management, including submission of the "DO-1 Declaration" in the relevant City Hall regarding the amount of the municipal waste management fee.

11. Regulation on the use of fire water network and marking and maintenance of hydrants at the Production Facility in Płock.

For activities related to checking, maintenance, functional tests of water sprinkling installations as well as organization of tactical and combat exercises (maneuvers), a fire water network is used.

The unreconciled collection of water from the main fire network and internal fire water networks installed on production installations and the use of equipment installed on them for purposes not related to fire protection is prohibited.

In exceptional and justified cases, it is allowed to periodically use the fire water network for purposes not related to fire protection, based on the written permission obtained for the collection of fire water.

A written application for permission to collect fire water for purposes not related to fire protection is submitted to the manager the Water Production Unit (SWP) in the Water & Wastewater Plant (PWS) or a person authorized by it:

- for the needs of the organizational units of PKN ORLEN S.A. – the manager of the interested organizational unit or a person authorized by him,
- for the needs of other recipients - a person authorized on behalf of the company, etc.

A written permit for the collection of fire water is issued by the manager of the Water Production Unit (SWP) in the Water & Wastewater Plant (PWS) or a person authorized by it.

The obligation to use pressure reducers for water intake from the fire water network.

The Issuer of the above mentioned permit shall send information in this matter by e-mail to:

- Company Fire Brigade,
- Wastewater Unit.

Permission for temporary, short-term use of the fire water network by the organizational units of PKN ORLEN SA can be issued by the the manager the Water Production Unit (SWP) or a authorized person authorized by him – on working days, while during his absence (non-working days, 2nd shift) - Master of Production Processes - Shift manager of the Water Production Unit, after informing about the fact the Company Fire Brigade.

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For activities related to checking, maintenance, functional tests of water sprinkling installations and semi-permanent foam fire-extinguishing systems as well as organization of tactical and combat exercises (maneuvers), a fire water network is used and in the case of rinsing the intra-plot network, it is required to obtain approval from the Master of Production Processes - Shift manager of the Water Production Unit and Wastewater Unit).

Immediate interruption of fire water intake for purposes not related to rescue and extinguishing operations takes place in the case of the necessity of carrying out rescue and firefighting operations.

The following are authorized to make a decision to immediately stop the collection of fire water:

- Manager of the Water Production Unit in the Water & Wastewater Plant or a person authorized by him,
- person managing the Water & Wastewater Plant,
- Master of Production Processes - Shift manager of the Water Production Unit (non-working days, 2nd shift),
- Head of Company Fire Brigade or a person authorized by him,
- Shift dispatcher of the Water and Wasteland Plant,
- Manager of the organizational unit, in which there is a fire water intake point.

Persons issuing permits for the collection of fire water and the Company Fire Brigade are obliged to immediately issue a ban on collecting fire water from the network in the event of non-compliance with the permit or arbitrary collection by the user.

Outdoor hydrants should be marked in accordance with the applicable legal regulations in accordance with PN-97 / N-01256/04, item 220. The marking applies to both hydrants belonging to the main network and to the intra-plot network. Consultation on the correct marking of hydrants is provided by the Water & Wastewater Plant.

SAFETY STANDARDS OF PKN ORLEN S.A.

List of regulations, standards and guidelines applicable to the classification of potentially explosive atmospheres

1. Regulation of the Minister of Interior and Administration of 7 June 2010 on fire protection of buildings, other construction objects and areas (Journal of Laws of 2010, No. 109, item 719).
2. Regulation of the Minister of Economy of November 21, 2005 on technical conditions to be met by liquid fuel bases and stations, long-distance pipelines for the transport of crude oil and petroleum products and their location (JoL. 2014, item 1853, as amended).
3. Regulation of the Minister of Economy of 8 July 2010 on minimum requirements regarding health and safety at work, related to the possibility of an explosive atmosphere in the workplace, (JiL of 2010 No. 138, item 931).
4. PN-EN 1127-1 Explosive atmospheres. Explosion prevention and explosion protection. Basic concepts and methodology.
5. PN-EN 60079-10-1 Explosive atmospheres. Classification of space. Gaseous explosive atmospheres.
6. PN-EN 60079-10-2 Explosive atmospheres. Classification of space. Atmospheres containing combustible dust.
7. PN-EN 50272 Safety requirements and installation of secondary batteries.

Appendix No. 2.1

List and characteristics of explosive hazardous materials.

[illegible]

List and classification of potentially explosive atmospheres

No. of classified space	Name of classified space	The type of space	Classification of space
1	2	4	5

Please note:

In accordance with the Fire Protection Act of August 24, 1991 and the Ordinance of the Minister of Interior and Administration of June 7, 2010 on fire protection of buildings, other structures and areas for existing facilities, with a complete facility consistent with the actual state, classification documentation for potentially explosive atmospheres, classification of workplaces where explosive atmospheres may occur, the following markings should be taken:

- a) **zone 0** - for zone Z 0 and for zones of category W I, in which the explosive atmosphere occurs permanently or permanently under normal operating conditions;
- b) **zone 1** - for zone Z 1 and for zones of category WI, in which the explosive atmosphere occurs periodically under normal operating conditions and zones of category W II, in which the explosive atmosphere may be prolonged;
- c) **zone 2** - for zone Z 2 and for zones of category WII, in which the explosive atmosphere may occur only temporarily, and for zones of category W III;
- d) **zone 20** - for zone Z 10 and for zones of category W IV;
- e) **zone 21** - for zone Z 11 and zone W V, for which an explosive atmosphere in the form of a cloud of flammable dust in the air can sometimes occur during normal operation;
- f) **zone 22** - for zone Z 11 and zone W V, for which an explosive atmosphere in the form of a cloud of flammable dust in the air does not occur during normal operation, and in case of occurrence it is short

The result of the explosion risk assessment

Item	Identified explosive atmospheres			Identified potential sources of ignition		Risk of explosion		
	Name of classified space	The probability of an explosive atmosphere	Type of danger zone	Type	The probability of occurrence of an ignition source	P - probability of explosion (the product of columns 3 and 6)	S	R
1	2	3	4	5	6	7	8	9
1				Flames and hot gases				
				Electrical equipment (electrically generated sparks)				
				Static electricity				
				Thunder Strike				

Where: P - the probability of explosion as a product of the probability of the appearance of effective ignition sources and the occurrence of an explosive atmosphere

S - explosion effects determined on the basis of matrix from point 3.3. We accept the highest category designated for individual groups (Employees, Population, Environment, and Property).

R - explosion risk determined on the basis of the matrix from point 3.3.

List of potentially explosive workplaces

Item	Workplace	The employee's business position	No. of space and type of explosion hazard zone	Risk of explosion
1	2	3	4	5

Note: In the column "No. of space and type of explosion hazard zone", the possibility of occurrence of more than 1 classification card should be taken into account. In column 5, enter explosion risk estimated in point 3.3

Specification of explosion-proof devices (example PiA)

Data from the device's rating plate					Classification data					Remarks measuring circuit numbers	Authorization, opinion / signature
Item	Name and type of device	Manufacturer by:	Name of the certification body, certificate number	Explosion-proof device and ATEX marking	Type of Ex zone	Explosion group and temperature class	Workplace (open / closed space)	Quantity	Another certificate number (according to the list of attached certificates)		
1	2	3	4	5	6	7	8	9	10	11	12

List of certificates for explosion-proof devices

Consecutive serial number of the certificate	Certificate number	Feature of the device	ATEX marking	Manufacturer, name and type of device	EU declaration of conformity



Conducting hazard analysis and physical effects assessment of process safety events

Appendix No. 2.7

1. DEFINITIONS

PHA Analysis (Preliminary Hazard Analysis) – is a method based on a systemic approach that allows for full identification of hazards thanks to the knowledge of the persons performing and participating in the analysis.

HAZOP Analysis (Hazard and Operability Study) – is a universal analytical method consisting of the systemic identification of potential hazards and related potential losses (e.g. a reduction in product quality).

LOPA (AWZ) – (Layer of Protection Analysis) is a method that allows to assess the effectiveness of the safety and security systems used in the context of the hazards defined by representative process safety events (PL: Reprezentatywne Zdarzenia Awaryjne - RZA).

2. SCOPE

The standard covers the minimum requirements for conducting hazard analysis and physical effects assessment for identified process safety events in the scope of:

- process risk matrix,
- methodology of hazard analysis (PHA, HAZOP, LOPA) as well as reliability data and correction factors,
- assessment of the physical effects of process safety events.

3. EXCLUSIONS

If the national rules are more restrictive than this Standard, they apply.

4. RESPONSIBILITIES

Persons involved in the process of commissioning, initiating, conducting, giving opinions, accepting risk analysis and effects assessment as part of the ongoing investment tasks and during periodic safety reviews / analysis of facilities located on the premises owned by PKN ORLEN S.A., in particular the production plant in Płock, PTA Plant in Włocławek, CCGT Plant in Płock, CCGT in Włocławek, Fuel Depots and other facilities that may be the place of process safety accident, both on the part of PKN ORLEN S.A., companies of ORLEN Group and external contractors.

5. REQUIREMENTS

5.1. General requirements

In accordance with the adopted practice and the provisions of the Disposition on: the application of the Process Safety Management System at the Polski Koncern Naftowy ORLEN S.A. to analyze process risks at PKN ORLEN S.A. the three most representative and universal types of analysis in the process safety industry are primarily used:

1. PHA analysis,
2. HAZOP analysis,
3. LOPA analysis.



Conducting hazard analysis and physical effects assessment of process safety events

In addition to the above-mentioned methods of analysis, it is also possible to use another commonly used method in individual cases, such as What if?, Event Tree Analysis ETA, Fault Tree Analysis FTA, etc. The methodology for carrying out these analysis is available in the industry literature or in publicly available sources, e.g. the Internet. Each time the need to use a different method of analysis than the three above-mentioned should be agreed with a representative of the Process Safety Team.

The purpose of a more detailed analysis, mainly of the effects of the identified process safety events (also called events), is the assessment of the physical effects, i.e. the impact of radiation level from fires, the overpressure resulting from an explosion and dispersion of toxic clouds. Such an assessment of physical effects can also be performed as part of safety analysis for the siting of new facilities on the premises of already existing facilities, with all kinds of modernizations, changes in the location of existing facilities, and emission of all kinds of gases in the process safety analysis of technological facilities. For this purpose, software available on the market is used to calculate the effect zones of the above-mentioned impacts and their presentation on maps, plot plans of plants / facilities. At PKN ORLEN S.A. the DNV PHAST software is used for this purpose. For this reason, it is the preferred software as part of investment tasks or for the purposes of other analysis for facilities owned by PKN ORLEN S.A. Nevertheless, it is allowed to perform the assessment of physical effects in other software, but in accordance with the principles described in the standard.

In the case of risk analysis and physical effects assessments prepared by external companies, the analysis report should be prepared primarily in Polish and the language of the contract in accordance with the provisions of the contract. Polish is the preferred language for conducting risk analysis. If the analysis is carried out in a foreign language, the presence of an interpreter using the technical language used in the given industry should be provided.

5.2. Minimal requirements concerning conducting hazard analysis

Hazard analysis can be started after collecting the required documents and data necessary to carry out a specific type of analysis and enabling the analysis to be carried out in an effective and efficient manner in the time planned, adequately to its scope. In the event of failure to provide materials in consultation with the stakeholders of a given analysis, a decision may be made to postpone the date of its conduct or extend its duration than initially planned. Therefore, it is important to define the composition of the team to carry out the analysis and to prepare an order appointing the team. In the course of risk analysis, the process risk matrix presented below is used together with a description of the impact category.

It should be noted that the analyzed solutions present the state of knowledge at the time of designing / implementing a given object. Hence, before starting the preparation / update of the analysis, which object is (or will be) covered, it is necessary to identify possible best practices available regarding the analyzed object and assess the possibility of their implementation into the existing P&ID.

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Fig. 1. Process risk matrix

Consequence category (S) Likelihood range 1/year (P)			<i>negligible</i>	<i>minor</i>	<i>moderate</i>	<i>serious</i>	<i>catastrophe</i>
			<i>Numerical symbol</i>	1	2	3	4
<i>very frequent</i>	<10 ⁰ – 10 ⁻¹)	1	TA	TNA	NA	NA	NA
<i>frequent</i>	<10 ⁻¹ – 10 ⁻²)	2	TA	TNA	TNA	NA	NA
<i>probable</i>	<10 ⁻² – 10 ⁻³)	3	TA	TA	TNA	TNA	NA
<i>occasional</i>	<10 ⁻³ – 10 ⁻⁴)	4	A	TA	TA	TNA	TNA
<i>rare</i>	<10 ⁻⁴ – 10 ⁻⁵)	5	A	A	TA	TA	TNA
<i>very rare</i>	<10 ⁻⁵ – 10 ⁻⁶)	6	A	A	A	TA	TA
<i>almost improbable</i>	<10 ⁻⁶ – 10 ⁻⁷ >	7	A	A	A	A	A

where:

- A** Acceptable risk (in theory, no additional safety measures are required, but may be indicated for implementation)
- TA** Tolerable-acceptable risk (ALARP rule, ang. As Low As Reasonably Possible – i.e. as low as possible within the resources committed to disposal, make review of alternatives)
- TNA** Tolerable unacceptable risk (implement additional safety and protection measures on separately agreed term)
- NA** Unacceptable risk (stop the process immediately)



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Tab. 1. Consequence categories

Consequences	Personnel	People	Environment	Property damage	Reputation
negligible	No injuries	No injuries	No impact	Loss less than 10 000 €	No impact
minor	Individual injuries (Not affecting the performance of work or rendering incapable of work)	Odours, noise (No evacuation of the population or first medical aid required)	Little, note down in reports (Light environmental damage within the process unit)	Loss less than 100 000 €	Minor impact (Shaken trust – quickly recoverable at low cost There may be public awareness)
moderate	Moderate injuries, individual heavy injuries (Limiting the performance of duties or absence for several days to fully recover; small, reversible health effects, e.g. skin irritation, food poisoning)	Little injuries (No evacuation required, first aid required)	Moderate devastation (Clearly devastation or emission to the environment but no lasting effect; a single breach of a statutory restriction or a single complaint)	Loss less than 1 000 000 €	Limited impact (Broken trust – possible to regain over time with PR support .. Unfavorable attention from local media / political groups)
serious	Numerous heavy injuries (Irreversible health effects with severe incapacity for work, e.g. burns with caustic agents, hearing loss caused by noise, detonation, heat stroke)	Moderate injuries (Limited health effects for people, no evacuation required, medical assistance required for individual cases)	Serious devastation (The company must undertake extensive efforts to restore environmental damage; the extent of the damage is in breach of statutory restrictions)	Loss less than 10 000 000 €	National impact (Significant drop in trust – trust can be regained over time, but at high cost. Extensive, unfavorable attention from the domestic media)
catastrophe	Fatal injuries (Single or collective fatal accident)	Heavy injuries (Irreversible health effects, required evacuation and medical assistance for a large number of people)	Ecocatastrophe (Permanent, serious damage to the environment resulting in large financial consequences for the Company; ongoing effects seriously violate statutory restrictions)	Loss exceeding 10 000 000 €	International impact (Seriously damaged trust – Impossible to fully recover. International Public Attention; extensive, unfavorable attention from the international media)

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5.2.1. PHA METHOD (PRELIMINARY HAZARD ANALYSIS)

① Purpose of PHA analysis

The purpose of the PHA analysis is to identify all potential hazards that may occur in a given facility.

② Scope of PHA analysis

The scope of the PHA analysis includes:

- division of the facility into the so-called analysis nodes (process units or unit operations with specific functions) subject to analysis,
- establishing the so-called the depth of the analysis, i.e. the level of detail of the analysis,
- determining the duration of the analysis in accordance with the previously planned deadlines and verifying the availability of funds for its performance.

③ Stages of PHA analysis

Conducting a PHA analysis is a multi-stage process which consists of:

1. collecting the necessary information and materials regarding the process unit,
2. selecting an analytical team,
3. acquainting team members with information and materials related to the installation,
4. performing the analysis along with keeping records of the analysis,
5. analysis of the results,
6. verification of additional recommendations,
7. preparation of the final report.

1) Gathering the necessary information and materials

Information and materials concerning the analyzed process unit should include:

- process unit location and external relations with other units,
- Material Safety Data Sheets,
- technological, operational and emergency instructions,
- specification of the main process units (apparatus),
- quantities of hazardous substances,
- technological and process diagram, including basic control and measurement equipment,
- data on existing safety and protection measures (safeguards),
- supply of energy media.

The analysis is performed by the analytical team after immediately familiarizing themselves with the materials and after conducting a field inspection of the installation (if necessary). In exceptional situations, when all the documents from the above list are not available, the decision to allow for analysis is made by a representative of the Process Safety Team or the Chairman of the analytical team. However, up-to-date and complete piping and instrument diagrams (P&I Diagrams) are the basis for the analysis.

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2) Performing the analysis along with keeping records of the analysis

PHA analysis is performed according to the so-called keywords representing potential sources of hazards. The checklist of sources of hazards that should be taken into account is given in Table 2.

For each selected node, substance and then the type of hazard, the reasons for the occurrence of these hazards, physical effects and consequences, the type of occurring or designed safety and security systems should be specified.

Tab. 2. Keywords for performing the Preliminary Hazard Analysis (PHA)

<i>General level</i>	<i>Establishment / process unit level</i>			<i>Technological section level</i>
<i>Material hazards</i>	<i>Natural hazards</i>	<i>External hazards</i>	<i>Location related hazards</i>	<i>Process hazards</i>
Substance properties: ➤ toxic, ➤ flammable, ➤ explosive, ➤ oxidizing, ➤ self-igniting, ➤ cancerogenic	➤ Earthquake, ➤ Floods, ➤ Wind, ➤ Extreme weather conditions	➤ Fall of the plane, ➤ Sabotage, ➤ Environmental surroundings, ➤ High voltage lines, ➤ Third party action	➤ Distances, ➤ Access, ➤ Evacuation, ➤ Interaction with other units/ objects/ establishments	➤ Loss of integrity, ➤ Fire, explosion, ➤ Particles, ➤ Exothermic reactions, ➤ Interaction with other nodes (cuts, control), ➤ Loss of power and communication

Entries under the conducted analysis are made in the worksheet presented in Table 3, which are part of the analysis report.



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Tab. 3. PHA analysis worksheet (example)

Unit: Node:			Figure:					
Hazard	Causes	Consequences	Existing safeguards	P (likelihood range)	S (consequence category)	R (risk level)	Recommendations	Responsible party

Remark: With regard to the used titles of the headings of individual columns of the spreadsheet, other synonymous terms may be used individually or jointly, e.g.:

- causes – probable causes, possible causes, etc.,
- existing safeguards – safety, safety measures, safety solutions, etc.,
- recommendations – additional safeguards, recommendations, recommendations, required actions, etc.,
- responsible – responsible person, area of responsibility, activity assigned to ..., etc.

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3) Results analysis

After identifying all selected analysis nodes, the results are analyzed. First of all, individual provisions (process safety events scenarios) should be ranked according to the increasing level of risk, i.e. A, TA, TNA and NA).

For further analysis, i.e. the selection of a list of process safety events scenarios (LZA), one takes into account those process safety events that have been assessed at the TNA and NA risk levels and, additionally, those scenarios that have been selected by the Analytical Team or the Process Safety Team as the worst consequences and the most frequent.

In this way, a list of process safety events (LZA) is created, which can then be simplified to the so-called list of representative process safety events (RZA). The list is selected by the Analytical Team during the implementation of analytical activities or the Process Safety Team if it is necessary to indicate them additionally after its completion. From a practical point of view, the choice of RZA is recommended in the case of analysis for the entire analyzed technological unit, i.e. a production installation / plant. It is not recommended to select RZA for small scope being the subject of the analysis, i.e. a node that is an element of the entire technological unit, a tank farm, a pump station with piping, in order to avoid creating an excessive number of emergency events and their duplication.

The following selection rules can be used as simplification criteria:

1. the emergency event for different substances with similar hazardous properties can be replaced by one representative substance,
2. release of liquefied substances or superheated liquids are usually represented by releases of a liquid phase (the gas or vapor phase is not taken into account),
3. The release of a substance from the same repeating apparatus (pumps, reactors, exchangers) is represented by the source which has the greatest operational parameters (pressure and temperature),
4. release of substances from the same repeating apparatus and devices, located in a close location, are replaced by one representative event in one location,
5. release, the probability of which is almost impossible due to the effective and multi-layered security system is eliminated,
6. releases not showing signs of a major accident (small leaks, leaks) may be represented by larger unsealing.

The list of RZA events is the basis for the development of emergency scenarios and further analyzes and calculations.

4) Recommendations

For those hazards for which the level of risk has been assessed at the level of TNA and NA and TA in accordance with ALARP, a proposal for additional technical and / or organizational safeguards should be established. The necessary records are made in the worksheet given in Table 4. In justified cases, it is also possible to specify additional safety measures for A-level hazards.

Taking into account additional safeguards, it is necessary (in accordance with the Process Risk Matrix) to assess their impact on:

P – likelihood range (1 - 7) – likelihood range of consequences in the Process Risk Matrix,
S – potential consequences (1 - 5) – category of consequence from Process Risk Matrix,
R – risk level (A, TA, TNA or NA).

It is expected that introduction of additional safeguards reduce the level of risk from TNA or NA to TA or A.

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Tab. 4. List of recommendations (example)

RPSE no.	Description of additional safeguard	Safeguards impact assessment on P, S i R			Responsible party	Term
		P	S	R		

5) Final PHA analysis report issuing

Final PHA analysis report should include:

1. Subject and scope of the analysis,
2. Composition of the Analytical Team,
3. List of documents being the basis for the analysis,
4. Worksheets,
5. List of RZA events (representative emergency events) - optional,
6. Conclusions on the level of risk,
7. Conclusions regarding the list of additional technical and organizational (security) recommendations,
8. Distribution list according to which the final analysis report was submitted.



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Tab. 5. Sample template in PHA worksheet (example)

Unit: Node:				Figure:				
Hazard	Causes	Consequences	Existing safeguards	P (likelihood range)	S (consequence category)	R (risk level)	Recommendations	Responsible party
Pipeline outlet from the tank (Flammability)	Release from pump or flange seal	Cloud formation, early or late ignition, fire, flash or spatial explosion	Hydrocarbon detectors, Sprinkler installation	3	2	TA	Not required	
Release from the tank	Corrosion	Cloud formation, early or late ignition, pool fire or spatial explosion	Tray, Hydrocarbon detectors, Sprinkler installation	3	3	NA	Introduce the construction of a double shell, renovation of the tank	Investor / User / Maintenance Services

The above PHA sheets constitute the documentation of the analysis and constitute an attachment to the final report.

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5.2.2. HAZOP METHOD (HAZARD AND OPERABILITY STUDY)

① Purpose of HAZOP analysis

The purpose of the HAZOP analysis is to identify all potential hazards and losses that may occur in the process unit.

② Scope of HAZOP analysis

The scope of the HAZOP analysis includes:

- division of installations into the so-called research nodes (process units or unit operations with specific functions) subject to analysis,
- establishing the so-called the depth of the analysis, i.e. the scope of the analysis detail,
- determining the duration of the analysis and the availability of funds.

③ Stages of HAZOP analysis

Carrying out the HAZOP analysis is a multi-stage process which consists of:

- a) collecting the necessary information and materials regarding the installation,
- b) selection of the Analytical Team,
- c) familiarizing team members with information and materials related to the installation,
- d) performing the analysis along with keeping records of the analysis,
- e) analysis of the results,
- f) verification of additional recommendations,
- g) preparation of the final report.

1) Gathering the necessary information and materials

Information and materials concerning the analyzed installation should include:

- process description,
- technological and process diagram (PFD diagram) and / or instrumentation and piping diagram (P&I Diagram),
- equipment specifications,
- installation maps,
- information on process and protection automation,
- technological, operational and emergency instructions,
- list of substances used and their characteristics,
- alarm and interlock operation program,
- standards and material specifications of pipelines,
- description of the valve closing sequence,
- description of vents and discharge systems and the output data for their design,
- physical and chemical properties of materials, intermediates and products (material safety data sheets),
- material balances,
- wiring diagrams.

Remark: The basis for the analysis are P&ID diagrams.

If it is not possible to complete the complete documentation mentioned above, the decision to perform the analysis is made by:

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- a) the person in charge of the Process Safety Team at the analysis planning stage or
- b) Chairman of the Analytical Team at the stage of analysis implementation.

The analysis is performed by the Analytical Team after immediately familiarizing themselves with the materials and performing an on-site inspection of the installation (if necessary).

2) Performing the analysis along with keeping records of the analysis

The HAZOP analysis is performed according to the so-called keywords representing potential sources of hazards. Keywords are created by combining lead words with an appropriate process parameter. Table 6 shows the watchwords and table 7 the process parameters.

In order to perform the analysis, the unit should be divided into the so-called research nodes (process units or unit operations with specific functions). Each research node is the next step in the analysis.

There are two options for dividing the unit into test sections (nodes):

- Traditional HAZOP, in which all main vessels, devices and connecting pipelines are taken into account sequentially, and they constitute individual so-called research nodes; e.g.: storage tank, pipeline, pump, valve, process reactor.
- A procedural HAZOP that takes into account the individual steps or activities included in the operating procedures, e.g. product storage, transport from the storage tank to the reactor and the reactor process.

PROCESS UNIT			
Node 1(step 1)	Node 2(step 2)	Node 3(step 3)	Node 4(step 4)
e.g. main pipeline	e.g. storage tank	e.g. pump	e.g. furnace
← FUNCTIONAL WHOLE →			

For each selected node, substance and then the type of hazard, the reasons for the occurrence of these hazards, physical effects and effects, the type of existing or designed safety and security systems should be specified.

Table 6. Keywords for keyword formation in HAZOP analysis

Keyword	Meaning
no (none)	negation of intentions
more / less, greater / less	quantitative increase / decrease
better / worse	qualitative increase / decrease
opposite	counterproductive
different	other than intended
other than	complete replacement
before / after, before / after	change over time
partly, too	qualitative lowering
also like, in addition to	qualitative increase

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Table 7. Parameters for creating keywords in HAZOP analysis

Flow	Time	Frequency	Mixing
Pressure	Composition	Viscosity	Addition
Temperature	pH	Voltage	Separation
Level	Velocity	Information	Reaction
Operation	Emptying	Maintenance	Corrosion
Mode of operation	Location	Load	Auxiliary medium*
Power supply	Atmospheric conditions	Concentration	Density
Relaying	Integrity	Other	Other (to be established by the Analytical Team)

* auxiliary medium - e.g. P&A air, repair / process air, heating steam, process / repair nitrogen, circulating water, fire water, refrigerant, lubricant, sealing agent, activated carbon, sorbent / filler

By combining the appropriate parameter with the keyword, you can create the keyword by which the HAZOP analysis is carried out (e.g. no flow, more flow, less flow, reverse flow, etc.).

It is important to consult individual parameters and keywords one by one to continue the analysis.

1. Division of installations into research nodes.
2. Selection of the first node, which is usually the first process operation or process apparatus.
3. Select the first appropriate keyword (a deviation that may be realistic) and start your analysis by finding:
 - the reasons for the occurrence of this deviation,
 - the expected effects of this deviation,
 - applied or designed safety and security systems (safeguards);

In addition, for each type of deviation, the likelihood of consequences (P), the category of consequences (S) and the resulting risk level (R) should be estimated. These effects include various operational problems as well as fires, explosion or toxic releases, and safeguards are measures to prevent, limit and counter the effects of these deviations.

The analysis continues for the next keywords and next unit nodes.

Records of the performed HAZOP analysis are made in the worksheet presented in Table 8 (formula), which constitute the documentation of the analysis.



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Table 8. HAZOP analysis worksheet (template)

	Unit	Node	HAZOP Worksheet		Documentation no.				Date: Team:	
No	Parameter	Deviation	Causes	Consequences	Safeguards	P (likelihood range)	S (consequence category)	R (risk level)	Recommendation	Responsible party
1.	temperature	temperature higher than 40 degrees Celsius	damage to the manual valve on steam 0.15 MPa	reaching the maximum temperature for 0.15 MPa steam in the tank, not exceeding its design parameters	Vapor pendulum – pressure equalization with the storage tank	4	2	TA	Enter the signaling of exceeding the limit temperature on the steam system	Maintenance services / User
					Breathing valves on the tank BV-1, BV-2					
					Workplace instructions, constant supervision during unloading					
					Technical calculation parameters of the tank strength					

The above HAZOP sheets constitute the documentation of the analysis and constitute an attachment to the final report.



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3) Analysis of the results

After analyzing all selected research nodes, the results are analyzed. The individual entries in the worksheets for each keyword and research node form certain sequences of events that can be called contingency scenarios. For further analyzes, i.e. the selection of a list of emergency events, one takes into account those emergency events that have been assessed at the TNA and NA risk levels, and additionally those scenarios that have been selected by the Analytical Team or the Process Safety Team as the worst effects and the most frequent.

In this way, a list of emergency events (LZA) is created, which can then be simplified to the so-called list of representative RZA emergency events. The list is selected by the Analytical Team during the implementation of analytical activities or by the Process Safety Team if it is necessary to indicate them additionally after its completion. From a practical point of view, the choice of RZA is recommended in the case of analyzes for the entire analyzed technological facility, i.e. a production installation / plant. It is not recommended to select RZA for small ranges being the subject of the analysis, i.e. a node that is an element of the entire technological facility, a reservoir park, a pumping station with piping, in order to avoid creating an excessive number of emergency events and their duplication.

The following selection rules can be used as simplification criteria:

7. the emergency event for different substances with similar hazardous properties can be replaced by one representative substance,
8. release of liquefied substances or superheated liquids are usually represented by releases of a liquid phase (the gas or vapor phase is not taken into account),
9. The release of a substance from the same repeating apparatus (pumps, reactors, exchangers) is represented by the source which has the greatest operational parameters (pressure and temperature),
10. release of substances from the same repeating apparatus and devices, located in a close location, are replaced by one representative event in one location,
11. release, the probability of which is almost impossible due to the effective and multi-layered security system is eliminated,
12. releases not showing signs of a major accident (small leaks, leaks) may be represented by larger unsealing.

The list of RZA events is the basis for the development of emergency scenarios and further analyzes and calculations.

4) Determining the list of additional security and implementation possibilities

For those threats for which the risk level has been assessed at the TNA and NA levels, and for TA (in accordance with the ALARP principle), a proposal for additional technical and / or organizational safeguards should be established and the feasibility of their implementation should be determined. The necessary records are made in the worksheet provided in Table 9.

Taking into account additional safeguards, it is necessary (in accordance with the Process Risk Matrix) to assess their impact on:

- P** – frequency of occurrence of effects (1 – 7) - frequency of effects in the Process Risk Matrix,
- S** – potential effects (category 1 – 5) - category of effects in the Process Risk Matrix,
- R** – risk level (A, TA, TNA or NA).

The introduction of additional safeguards is expected to reduce the level of risk from TNA or NA to TA or A.



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Table 9. List of additional safety measures (template)

RZA no.	Description of additional safeguard	Safeguards impact assessment on P, S i R			Responsible party	Term
		P	S	R		

5) Preparation of the final report on the HAZOP analysis

The final report on the HAZOP analysis should include:

1. Subject and scope of the analysis,
2. Composition of the Analytical Team,
3. List of documents being the basis for the analysis,
4. Worksheets,
5. List of RZA events (representative emergency events) - optional,
6. Conclusions on the level of risk,
7. Conclusions regarding the list of additional technical and organizational (security) recommendations,
8. Distribution list according to which the final analysis report was submitted.

5.2.3. LOPA METHOD (LAYER OF PROTECTION ANALYSIS)

Safety and protection systems in process units are an integral part of every unit and are formed in the so-called multi-layer security system also known as barriers.

There are three main layers of security:

1. prevention layer, the task of which is to prevent the occurrence of initiating events that may lead to the occurrence of dangerous operating conditions and, consequently, the release of substances (process automation, basic alarms and operator actions),
2. layer of protection, which is designed to protect the process facility and employees against the effects of the release (devices belonging to security automation, e.g. interlocks, critical alarms, shut-off valves and discharge systems, emergency shutdowns and safety valves and various active and passive fire and containment systems) effects of releases);
3. layer of countermeasures, aimed at minimizing the effects of the releases (fire brigade and rescue).

The identification of safety and security systems is mainly based on a detailed description of the unit, taking into account its location, chemicals, vessels, equipment and operating conditions. This is particularly important because the assumption of the **LOPA** (AWZ) analysis shows that the unreliability of these systems determines the occurrence of a serious industrial failure. This method is based on the accurate identification of the existing multi-layer safeguards.

The characteristic features of the multi-layer system of independent layers of protection (ILOP) are:

1. sequential, serial operation of each of the security layers triggered after the failure of the previous layer,
2. selecting the number of security measures in each layer depending on the scale of the hazards,
3. initiating the operation of layers of protection by a specific initiating event, which is usually a failure of elements operating in the prevention layer,
4. independence of each of the layers of protection in relation to each other and functioning in a different area of process unit operating conditions,



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5. ability to reduce the level of risk (likelihood and category of the consequences) by each of the layer of protection.

1 Purpose of LOPA analysis

The Layer of protection analysis consists in determining the probability of failure of the sequence of successive layers of protection and the applied protection measures. The analysis assumes that a serious failure may occur as a result of failure of individual layers. Calculations are made using mathematical formulas and taking into account the so-called generic data.

2 Algorithm during the LOPA analysis

The algorithm of proceeding in the layer of protection analysis LOPA (AWZ) concerns the representative process safety events (RZA) identified for a given unit and includes the following steps:

1. Analysis of RZA occurrence without security,
2. Analysis of the occurrence of RZA with collateral,
3. Risk assessment,
4. Analysis of the results.

The results of the analysis are recorded in the LOPA (AWZ) worksheet (Table 10).

1) Analysis of the RZA occurrence without security

The basic activities during the analysis of the occurrence of a representative process safety event (RZA) without security are:

1. Identification of a representative process safety event RZA(W) and RZA(P), i.e. the release of a dangerous substance,
2. Selection of the first RZA and estimation of the potential effects (S_0) of the analyzed RZA, using the determined categories of consequences presented in Table 1,
3. Determining the level of acceptable risk, i.e. the probability of occurrence such an RZW of based on the Process Risk Matrix (Figure 1),
4. Identification of the initiating event and determining the probability of its occurrence (f_i) [1 / year] – on the basis of Tables 11 and 12.
5. Estimating the likelihood of the so-called conditional events (P_W) and the probability of enabling events (P_U) to arise certain outcomes without taking into account the safeguards.
6. Calculating the likelihood of occurrence of consequences without safeguards (F_{BZ}) using the formula:

$$F_{BZ} = f_i \times \prod_1^n (P_W \times P_U) [1 / rok]$$

where:

F_{BZ} – frequency of occurrence of effects without safeguards,

P_W – probability of conditioning events (e.g. presence of a hazardous substance),

P_U – the probability of events enabling the occurrence of negative effects (e.g. occurrence of an ignition source),

rok – means year.

2) Analysis of the occurrence of RZA with safeguards

The basic activities during the analysis of the occurrence of a representative emergency event (RZA) with protections are:

1. Identification of independent security layers (NWZ) and estimation for each of them the probability of their failure on request (P_{NWZ}) based on the provided Tables 13, 14.



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2. Specifying other layers of security (IWZ) – without taking into account the quantity.
3. Calculation of the total value of the failure probability of security layers (P_S).

$$P_S = \left(\prod_i^n P_n \right)$$

4. Calculation of the frequency of occurrence of effects with collateral, i.e. the level of risk with collateral (R_{ZZ})

$$F_{ZZ} = P_S \times F_{BZ} \text{ [1/year] for consequences } S_0$$

where:

F_{ZZ} – the likelihood of occurrence of consequences with safeguards

P_S – the probability of failure of the layers of protection

F_{BZ} – the likelihood of occurrence of consequences without safeguards

3) Risk level assessment

During the risk assessment using the LOPA (AWZ) method, the overall risk level is determined from the Process Risk Matrix.

Taking into account the categories of consequences (S_0) (according to Table 1) and the calculated value of the likelihood of occurrence of consequences with safeguards (F_{ZZ}), the risk level (R_{ZZ}) is determined according to the Process Risk Matrix.

4) Determining the list of additional safeguards and implementation possibilities

For those hazards for which the level of risk has been assessed at the TNA and NA levels, it is absolutely necessary to establish a proposal for additional technical and organizational safeguards and to make arrangements for implementation possibilities. Additional recommendations can also be made for hazards with a risk level of TA and A, taking into account, for example, good engineering practice in the refining and petrochemical industry.

The introduction of additional safeguards is expected to reduce the level of risk from TNA or NA to TA or A.

The obtained results of the LOPA (AWZ) analysis will allow for the conclusion that:

- If $R(RZA)_{ZZ} < R(RZA)_{A-TA}$ then it is considered that the risk of a process safety event is acceptable and no additional tolerable protections are required.
- If $R(RZA)_{ZZ} > R(RZA)_{A-TA}$ then the risk of a process safety event related to the RZA event is considered unacceptable.

If it is found that the level of risk is unacceptable, then one should:

1. Introduce an additional layer of security,
2. Improve the applied security layers (reduce the probability of their failure at the request of P_{NWZ}),
3. Perform a more detailed analysis by using the error trees technique and quantitative risk analysis,
4. Estimate the impact of the proposed security on the risk level according to the same procedure.

The next step is to apply the event elimination criteria to develop a shortened list of representative process safety events (RZA).

5) Preparation of the final report on the LOPA (AWZ) analysis

The final report on the AWZ analysis should include:

1. Subject and scope of the analysis,



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2. Composition of the Analytical Team,
 3. List of documents being the basis for the analysis,
 4. Worksheets,
 5. List of RZA events (representative process safety events) – optional,
 6. Conclusions on the level of risk,
 7. Conclusions regarding the list of additional layers of technical and organizational security,
- Distribution list according to which the final analysis report was submitted.

Table 10. LOPA (AWZ) worksheet (template)

Section:	Process:	Type of event:	
Unit:	Vessel/equipment:	Event name:	
Analysis date:	Event scenario description:		
Substance:			
Hazard category:			
MSDS :	Lower tier [ton]:	Upper tier [ton]:	
Degree of release, U_{kol} :	Consequence category assessment, S_0 :	Risk level assessment	
Department:	PFD	Likelihood [1/year]	
Initiating event IE, (F_i)			
Conditioning event, (P_W)			
Events enabling the consequences mentioned in the scenario to arise, (P_U)	Probability of late ignition		
	Probability of wind direction		
	Probability of staying in the zone		
	Probability of death		
External events	Domino effects		
The frequency of the occurrence of unprotected effects	$F_{BZ} = f_i \times P_W \times \prod P_U$		=
Independent layers of protection (NWZ), P_{NWZ}			
Layer I (Prevention)			
Basic Process Control, operator actions and others			
Layer II (Protection)			
Safety automation, Safety valves and others			
Layer III (Counteraction)			
		Change of Consequence Category	
Security of a different kind (INZ)			
Operations of the company fire brigade within 5 to 10 minutes. (from -1 to -2)			
No activities of Company Fire Brigade and the activities of the State Fire Service within 30 min. (from -1 to 1)			
		S Value after correction	
Final probability P_s for all NWZ	$P_s = \prod P_{(NWZ)}$		
Probability of consequences with safeguards	$F_{ZZ} = P_s \times F_{BZ}$		
Identification of risk level	$R_{ZZ}(S) = f(F_{ZZ})$	Risk level assessment (A, TA, TNA, NA)	
Additional safeguards necessary to achieve the risk level at least TA			
Additional safeguards impact:	on F_{ZZ} :	on consequence cat. S_0 :	on risk level, R_{ZZ0} :
Reference documents:			
Assessment team:			



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5.2.4. RELIABILITY DATA AND CORRECTION FACTORS

The following tables 11-20 show various reliability data and correction factors that are recommended for use in the process risk assessment, including HAZOP, PHA, AWZ.

Table 11. Initiating events

Initiating events		
External events	Equipment failures	Human factor (oversights and omissions)
Storms, floods and other natural hazards, Falls of planes, Serious failures in the neighborhood, Sabotage or terrorism	Failures or malfunctions of control systems (BPCS) and autom. safeguards, Software errors, Mechanical failures: fatigue, corrosion, vibration, defects, use outside the design range	Operator errors, Maintenance errors, Incorrect response to alarms, Programming errors

Table 12. Initiating event likelihood used in the LOPA (AWZ) analysis

Frequency of the initiating Events applied in the AWZ analysis		
Type of initiating event	Likelihood range f_i [1/year]	Usually selected value to LOPA (AWZ) [1/year]
Pressure tank failure rupture	10^{-5} do 10^{-7}	1×10^{-6}
Pipeline rupture – 100m	10^{-5} do 10^{-6}	1×10^{-5}
Pipeline leakage	10^{-3} do 10^{-4}	1×10^{-3}
Atmospheric tank failure	10^{-3} do 10^{-5}	1×10^{-3}
Blowing out the gasket	10^{-2} do 10^{-6}	1×10^{-2}
Turbine overload with shaft breakage	10^{-3} do 10^{-4}	1×10^{-4}
Third party participation	10^{-2} do 10^{-4}	1×10^{-2}
Fall of the load carried by the crane	10^{-3} to 10^{-4} for lifting	1×10^{-4} for lifting
Thunder strike	10^{-3} do 10^{-4}	1×10^{-3}
Undesirable opening RV	10^{-3} do 10^{-4}	1×10^{-2}
Cooling system failure	1 do 10^{-2}	1×10^{-1}
Pump seal failure	10^{-1} do 10^{-2}	1×10^{-1}
Hose damage	1 do 10^{-2}	1×10^{-1}
BPCS system failure	1 do 10^{-2}	1×10^{-1}
Regulator failure	1 do 10^{-1}	1×10^{-1}
Small external failure	10^{-1} do 10^{-2}	1×10^{-1}
Big external failure	10^{-2} do 10^{-3}	1×10^{-2}
Human factor	10^{-1} to 10^{-3} on demand	1×10^{-2} on demand
Total multicomponent system failure	10^{-3} to 10^{-4} on demand	1×10^{-3} on demand



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Table 13. Failure probability of independent layers of protection (NWZ) – prevention layer

Failure probability of independent layers of protection (NWZ) prevention layer		
Safeguard type	Range P_{NWZ} . probability failure	Value P_{NWZ} . usually selected to LOPA (AWZ)
Good engineering practice	1*	1*
Activities of the services UDT	1*	1*
Inspections and services	1*	1*
Control and measurements automatics (BPCS) – then it is not the initiating event	1×10^{-1} to 1×10^{-2}	1×10^{-1}
Operator activity (operator response to primary alarms)	$>1 \times 10^{-1}$	1×10^{-1}
Cooling systems	1×10^{-1} to 1×10^{-2}	1×10^{-1}
Reaction inhibition systems	1×10^{-1}	1×10^{-1}
Emergency power and backup systems (backup power supply with electricity, water, steam, air, inert agents)	1×10^{-1} to 1×10^{-2}	1×10^{-1}

* – activities performed once a year and less frequently than once a year; it is not assumed that they will not be implemented or that a mistake has been made in the course of these activities.

("Guidelines for Initiating Events and Independent protection layers i Layer of Protection Analysis", CCPS, Aiche 2015)

Table 14. Failure probability of independent layers of protection (NWZ) – protection layer

Failure probability of independent layers of protection (NWZ) protection layer		
Safeguard type	Range P_{NWZ} . probability failure	Value P_{NWZ} . usually selected to LOPA (AWZ)
Safety valves	1×10^{-1} to 1×10^{-5}	1×10^{-2}
Safety plates	1×10^{-1} to 1×10^{-5}	1×10^{-2}
Operator response to critical alarms	1 to 10^{-1}	1×10^{-1}
Safety automatics – SIS (locks, automatic switches, ESD, burner control, fire and gas detection systems)		
SIL1 system – reliability of protection (single sensor, processor and actuator)	1×10^{-1} to 1×10^{-2}	1×10^{-1}
SIL 2 system – Multiple sensor, multi-channel processor and multiple actuator (with the so-called error tolerance)	1×10^{-2} to 1×10^{-3}	1×10^{-2}
SIL 3 system – multi-art. sensor, Easter. processor and size el. execution (no error tolerance)	1×10^{-3} to 1×10^{-4}	1×10^{-3}
Explosion suppression systems	1×10^{-1} to 1×10^{-2}	1×10^{-1}
Locking system-MOV	1×10^{-1} to 1×10^{-2}	1×10^{-1}



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Failure probability of independent layers of protection (NWZ) protection layer		
Safeguard type	Range P_{NWZ} probability failure	Value P_{NWZ} usually selected to LOPA (AWZ)
Discharge systems (collectors, flares, ab- and adsorbers, reactor discharges, scrubbers, discharge tanks).	1×10^{-1}	1×10^{-1}
Emergency cooling systems	1×10^{-1}	1×10^{-1}
Sprinkler systems	1×10^{-1}	1×10^{-1}
Detectors	$1 \cdot 10^{-4}$	In line with the release category
Foam systems / cannons	1×10^{-1}	1×10^{-1}
Concrete tray	1×10^{-2} to 1×10^{-3}	1×10^{-2}
Underground drainage system	1×10^{-2} to 1×10^{-3}	1×10^{-2}
Open vent to atmosphere	1×10^{-2} to 1×10^{-3}	1×10^{-2}
Fire resistance of steel and buildings	1×10^{-2} to 1×10^{-3}	1×10^{-2}
Explosion proof walls / bunkers	1×10^{-2} to 1×10^{-3}	1×10^{-2}
Anti-detonation / anti-flame filters	1×10^{-1} to 1×10^{-3}	1×10^{-2}

In the semi-quantitative method, depending on the adopted size of the outflow and the category of a dangerous substance, the **degree of release** is categorized into five categories from 1 to 5 based on the following table 15.

Table 15. Degrees of release

Substance category	Degrees of release					
	The size of the outflow					
	1-10 kg	10-100 kg	100-1000 kg	1000-10000 kg	10000-100000 kg	>100000 kg
	Pin	Leakage at the gasket	10-15 mm	25 mm	50-100 mm	> 100 mm
Acute Tox. 1 i 2, STOT SE 1	3	4	5	5	5	5
Acute Tox.. 2 (pary H330) i 3, STOT RE 1	2	3	4	5	5	5
Flam. Liq. 1 ,2 i 3, (H224 flash point <23°C and boiling point ≤35°C, H225 flash point <23°C and boiling point >35°C, H226 flash point ≥23°C)	1	2	2	3	4	5
Flam. Liq. 1 i 2, (H224 boiling point ≤ 35°C, H225 boiling point > 35°C)	1	2	3	4	5	5
Flam. Gas. 1 i 2, (H220, H221), Flam. Liq. 1 (H224, H242)	2	3	4	5	5	5
Hydrogen	2	3	3	4	5	5



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Crude oil distillation products	1	2	2	3	4	5
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When the substance is both flammable and / or toxic, and / or is a product of crude oil distillation, the value for the highest hazard is taken, i.e. for a substance that is both flammable and toxic, the value determined for toxicity is used.

It is possible to use all properties in the calculations in order to verify the greatest range and impact, taking into account the toxic and flammable properties as well as the specificity of crude oil distillation products.

Ignition is one of the main conditioning events. It is distinguished by immediate and delayed ignition. The incidence of ignition is expressed in the form of probability, which depends on many factors, mainly the type and amount of the released substance, location (process, storage or off-site area). Tables 16 and 17 present the assumed probability values depending on the amount of the released substance, distinguishing immediate ignition and delayed ignition.

Table 16. Probability of immediate ignition

Probability of immediate ignition		
Amount of released material, kg	Simple hydrocarbons	Extremely flammable substances Substance with MIE < 0.3mJ
1-10 kg	10^{-2}	10^{-2}
10-100 kg	10^{-2}	10^{-1}
100-1000	10^{-1}	10^{-1}
1000-10000	10^{-1}	1
10000-100000	10^{-1}	1
>100000	1	1

Table 17. Probability of late ignition

Probability of late ignition		
Amount of released material, kg	Simple hydrocarbons	Extremely flammable substances Substance with MIE < 0.3mJ
1-10 kg	10^{-4}	10^{-4}
10-100 kg	10^{-3}	10^{-3}
100-1000	10^{-2}	10^{-2}
1000-10000	10^{-1}	1
10000-100000	10^{-1}	1
>100000	1	1

The conditioning events related to the release of toxic gases are as follows:

1. Probability of wind direction according to the wind rose in the area; it varies from 0,05 to 0,25.
2. The probability of staying in the zone depends on the frequency of servicing the operator. It ranges from 0,01 to 1, depending on the type of tasks performed by the operator, e.g. when unloading tankers, it is the ratio of the duration of stay at unloading to the total number of hours.
3. The probability that the stay in the danger zone will cause a lethal effect (probability of death) for employees is assumed to be 0,5; for the population – 0,1.



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Table 18. Probability of human error

Probability of human error			
Safeguard type	Comment	Range P_{NWZ} - probability failure	Value P_{NWZ} usually selected to LOPA (AWZ)
Operator action within 10 min	Well documented procedure	from 1.0 to 10^{-1}	1×10^{-1}
Operator action on BPCS or alarm within time 40 min.	Good procedure and clear indicators	$>1 \times 10^{-1}$	1×10^{-1}
Operator action within 40 min.	Simple operation by procedure	1×10^{-1} to 1×10^{-2}	1×10^{-1}

Table 19. Values of the correction factors related to consequence categories

Values of the correction factors related to consequence categories		
Safeguards type – independent	Range of the correction factor	Correction factor
Communication system (sirens, alarms etc.)	Not quantified	No change
Handheld firefighting, rescue and medical equipment	As above	No change
Activities of unit Rescue	No change	No change
Company Fire Brigade activities within 5 to 10 minutes	from -1 to -2	Choose the expert. Suggested value (-1)
No activities of Company Fire Brigade and activities of State Fire Brigade within 30 minutes	from -1 to 1	Choose the expert. Suggested value (0)
Medical assistance	No change	No change
Internal emergency plans	No change	No change

The presence of a domino effect is established by establishing a zone of complete damage. The presence of secondary objects in this zone may cause this effect. The impact of the domino effect is characterized by the increased probability of a given contingency scenario. On the basis of numerous studies, it is considered that this effect can be maximally estimated at one order of magnitude. An algorithm for increasing the frequency of a given event is set by a correction factor varying from 1 to 10, depending on the size of the release.

Table 20. Values of the correction factors related to domino effect

Values of the correction factors related to domino effect						
Seveso category	Degree of release					
	1	2	3	4	5	6
	1- 10 kg	10 -100 kg	100 - 1000 kg	1000 - 10000 kg	10000 - 100000 kg	>1000000 kg
Flam. Gas. 1 i 2, (H220, H221), Flam. Liq. 1 (H224, H242)	3	4	6	8	10	10
Flam. Liq. 1 i 2, (H224 boiling point $\leq 35^{\circ}\text{C}$, H225 boiling point $>35^{\circ}\text{C}$)	2	3	4	6	8	10



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Values of the correction factors related to domino effect						
Seveso category	Degree of release					
	1	2	3	4	5	6
	1- 10 kg	10 -100 kg	100 - 1000 kg	1000 - 10000 kg	10000 - 100000 kg	>1000000 kg
Flam. Liq. 1 ,2 i 3, (H224 flash point <23°C and boiling point ≤35°C, H225 flash point <23°C and boiling point >35°C, H226 flash point ≥23°C)	1	2	3	4	7	8
Hydrogen	3	4	6	8	10	10

The correction factors given in Table 20 are indicative and recommended values. The final assessment of the size of the anticipated effects of the occurrence of secondary explosive and / or fire effects is always the responsibility of the analysis team, which in case of justified circumstances can significantly change the recommended value from the table.

The very occurrence of domino is associated with two simultaneous conditions:

1. The exposed object must be within the range of the hazard zone with the above-mentioned critical sizes;
2. A domino effect of a different nature may be triggered in the case of complete disappearance of various energy factors, which, however, in most cases comes down to an emergency shutdown of entire installations (eg ESD).

ASSESSMENT OF THE PHYSICAL EFFECTS OF REPRESENTATIVE PROCESS SAFETY EVENTS

In order to standardize the procedure during the assessment of the physical effects of representative accident events, the following rules are established in the software for modeling the releases of hazardous substances:

1. To determine the potential ranges of emergency scenarios in Polski Koncern Naftowy ORLEN S.A. a quantitative method is used, which consists in performing calculations of physical effects with the use of the PHAST computer program (or other dedicated software),
2. The release characteristics necessary for the determination, i.e. the assessment of the potential amount of the released substance, are made on the basis of two discharge models:
 - outflow from the tank and outflow from the pipeline,
 - type of discharge: rupture and leakage.

Considering the possible combinations, the following releases can be obtained:

- for the tank:
 - ▶ tank / column rupture: torn off the spigot with the largest diameter,
 - ▶ tank / column leakage: a hole with a diameter of 25 to 50 mm (the size of the hole depends on the size of the tank),
- for the pipeline:
 - ▶ pipeline rupture: outflow from the entire section,
 - ▶ pipeline leakage: bore corresponding to 0,01 to 0,1 of the pipe cross section.
- 3. The assumptions of Pasquill's atmospheric stability, which describe the level of turbulence in the atmosphere, are used for the calculations. Stability depends on wind speed, time of



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day, and other conditions as shown in Table 21 and described for each stability below the table. The selection of the class of atmospheric stability is made depending on the prevailing atmospheric conditions in a given location, as well as the meteorological conditions related to the wind rose, and the temperature and humidity of the atmosphere (e.g. for the Plock plant, the F2 and D3 classes are assumed).

Table 21. Pasquill atmospheric stability classes used to calculations

Pasquill atmospheric stability classes						
Windspeed	Day: solar radiation			Night: cloud cover		
[m/s]	Strong	Moderate	Slight	Thin <40%	Moderate	Overcast >80%
< 2	A	A-B	B	-	-	D
2 – 3	A-B	B	C	E	F	D
3 – 5	B	B-C	C	D	E	D
5 – 6	C	C-D	D	D	D	D
> 6	C	D	D	D	D	D

where:

A – very unstable – sunny, light winds,
 A/B – unstable – as with A only less sunny or more windy,
 B – unstable – as with A/B only less sunny or more windy,
 B/C – moderately unstable – moderate sun or moderate wind,
 C – moderately unstable – very windy/sunny or overcast/light wind,
 C/D – moderately unstable – moderate sun and high wind,
 D – neutral – little sun and high wind or overcast/windy night,
 E – moderately stable – less overcast and less windy night than D,
 F – stable – night with moderate clouds and light/moderate wind,
 G – very stable – possibly fog.

The above assumptions make it possible to calculate the size of the release based on appropriate models simulating the outflow of liquid, gas and the two-phase system of the PHAST program. These values are then automatically entered into the equations of the dispersion of substances in the atmospheric environment or other equations allowing to calculate the ranges of hazard zones for the established threshold criteria.

- For the calculation of the ranges of fire-explosion hazard zones and then the effects on people and property, used typical and widely used in Western countries the threshold criteria, which are given in Table 22, were applied.

Table 22. Threshold criteria for determining the zones of threats and effects

Threshold values for determining the zones of threats and effects		
Effect type	Consequences for people	Consequences for property
Thermal radiation		
37,5 kW/m ²	100% deaths within 1 min. 1% deaths within 10 sec.	damage to vessels and devices
12,5 kW/m ²	50% deaths within 1 min. – serious injuries within 10 sec.	secondary fires of flammable materials
4 kW/m ²	0% deaths, burns causes pain after 20 sec. – Injuries	lack
Overpressure		
0,45 bar (45 kPa)	100% deaths inside buildings and injuries outside buildings	solutions to the destruction of buildings and structures



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Threshold values for determining the zones of threats and effects		
Effect type	Consequences for people	Consequences for property
0,2 bar (20 kPa)	50% deaths inside buildings, injuries outside buildings	partial collapse of building walls
0,1 bar (10 kPa)	Injuries among people	buildings damages
0,05 bar (5 kPa)	People injuries inside buildings	cracking of windows
0,02 bar (2 kPa)	People injuries inside buildings	cracking of windows

5. For toxic effects, the following threshold criteria are used to define the extent of the toxic zones (Table 23).

Table 23. Threshold criteria for determining toxic hazard zones

Threshold criteria for determining toxic hazard zones		
Hazard type	Threshold criteria	The importance of the concentration size
Dispersion of toxic substances	ERPG 2	The maximum concentration of a substance in the air below which almost every person can be exposed for up to 1 hour without serious irreversible health effects or symptoms that may affect the ability to take protective measures;
	LCLo	LEL – Lowest Exposure Limit - The lowest concentration of a toxic substance in the air causing fatalities in humans and animals;
	PW	Detection threshold - the lowest concentration of a substance in the air felt by a human;
	NDS	HEL – Highest Exposure Limit The highest permissible concentration of substances in the air (weighted average), the impact of which on the employee during the 8-hour working time throughout the period of his professional activity should not cause negative changes in his health and in the health of his future generations
	NDSch	The maximum permissible instantaneous concentration of a substance in the air (average value), which should not cause negative changes in his health and the health of his future generations, if they remain in the work environment for no longer than 30 minutes during a shift

The threshold values listed in the tables above may also be selected individually according to the expectations or guidelines of the local public administration authorities or as a result of changes in the applicable national regulations in this regard.

6. The obtained ranges of hazard zones for individual threshold values are overlaid on the plant map and on this basis the number of people exposed to the most unfavorable effects, including fatalities and injuries, and types of objects exposed to total or partial destruction, is determined.



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5.3. Documentation requirements

The general documentation requirements for each type of analysis are described for each hazard analysis method. In addition, the details of the preparation of the analysis report in individual cases are agreed among the interested parties, while maintaining the requirements of the Ordinance on: the application of the Process Safety Management System at the PKN ORLEN S.A.

6. GOOD PRACTICES

At PKN ORLEN S.A. it is a good practice to require hazard analyzes (HAZOP, LOPA etc.) to be updated every 5 years. In case of introducing any technological changes to the process facility, the need for updating should be consulted with the process safety dept.